MEET THE CREEPY, CRAWLY HOME INVADERS

HOW IT WORKS

INSIDE A VERTICAL TAKE-OFF & LANDING JET

HOW CPR SAVES LIVES

+
- WHAT HORSE HOOVES ARE FOR
- GASTRIC BANDS EXPLAINED
- WHAT'S THAT BIG MOON CRATER?

10 INCOMING ASTEROIDS

HOW WE TRACK AND INVESTIGATE THE BIGGEST SPACE ROCKS HEADING EARTH'S WAY

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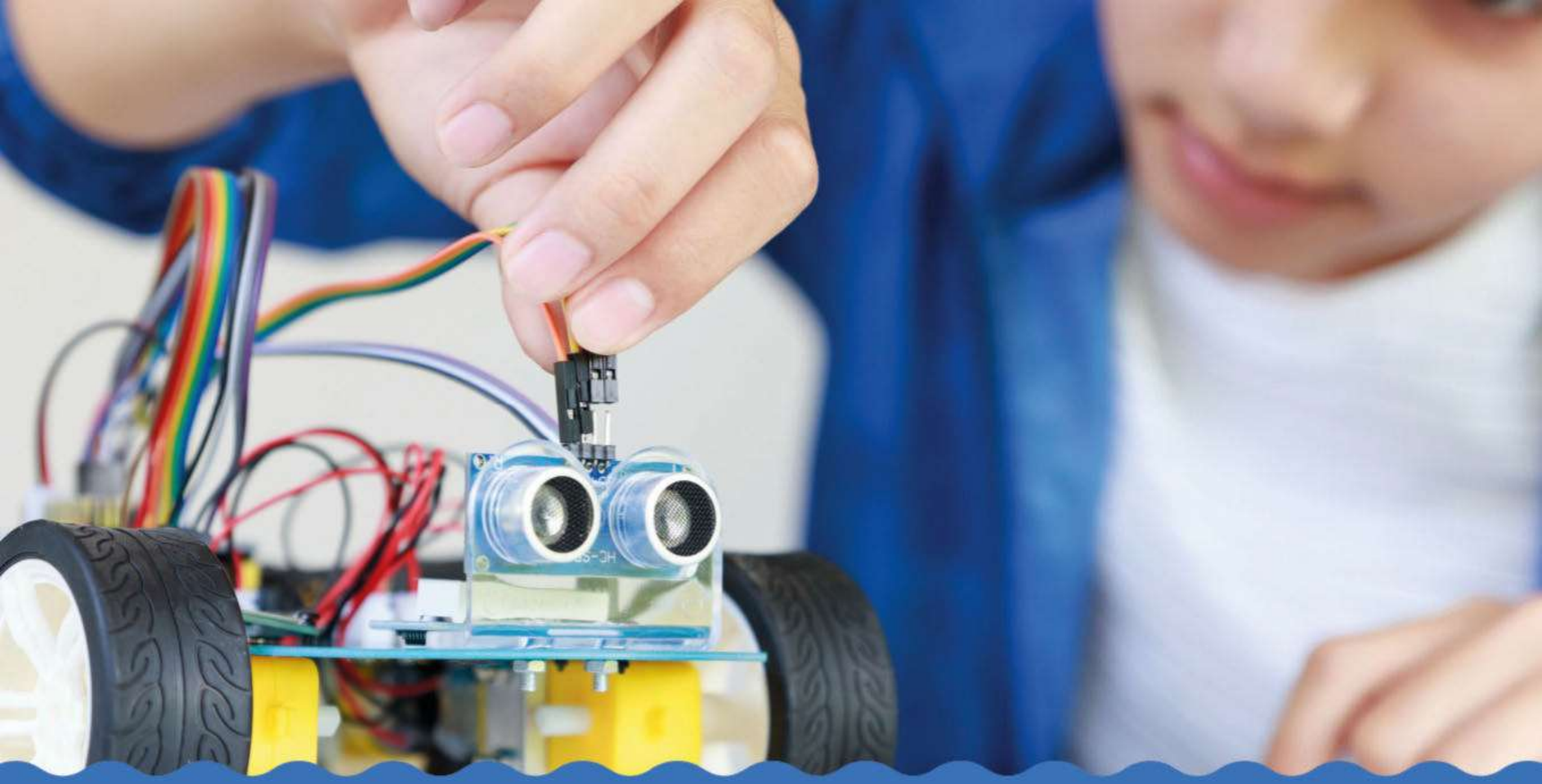

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WELCOME

Issue 178

> "The fact that an asteroid's orbit crosses Earth's doesn't automatically mean there's a collision risk"

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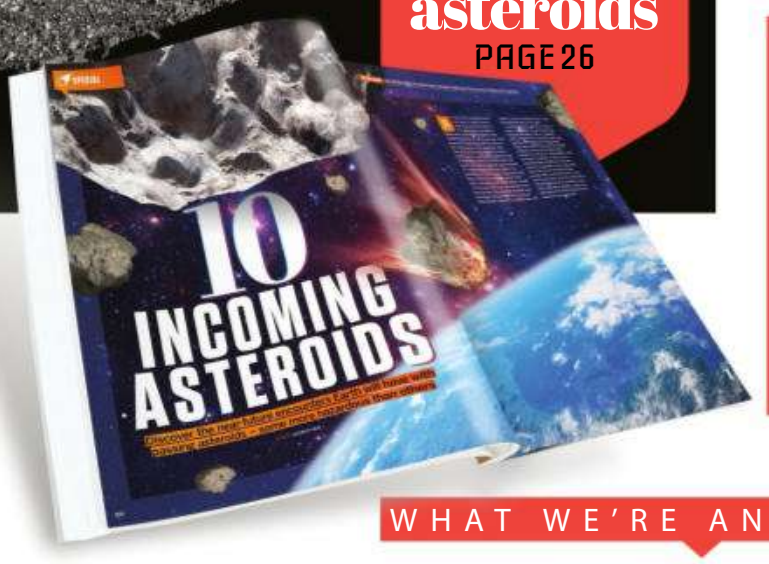
10 Incoming asteroids
PAGE 26



Asteroids and space rocks are even more interesting in real life than they are in science fiction movies: they can measure tens of kilometres in diameter, contain a trillionaire's fortune in precious metals, and are considered to be the building blocks of the Solar System. Some theories even credit them with bringing life to Earth from another planet, billions of years ago. Of course, an especially large asteroid hitting Earth could end life as we know it, although that's not the only reason why astronomers monitor them. In this issue of **How It Works**, we're taking a look at ten asteroids that will be making a close approach to Earth in the near-future, discovering what they're made of and how science can benefit from observing them. Enjoy!

Ben Biggs
EDITOR

HIGHLIGHTS

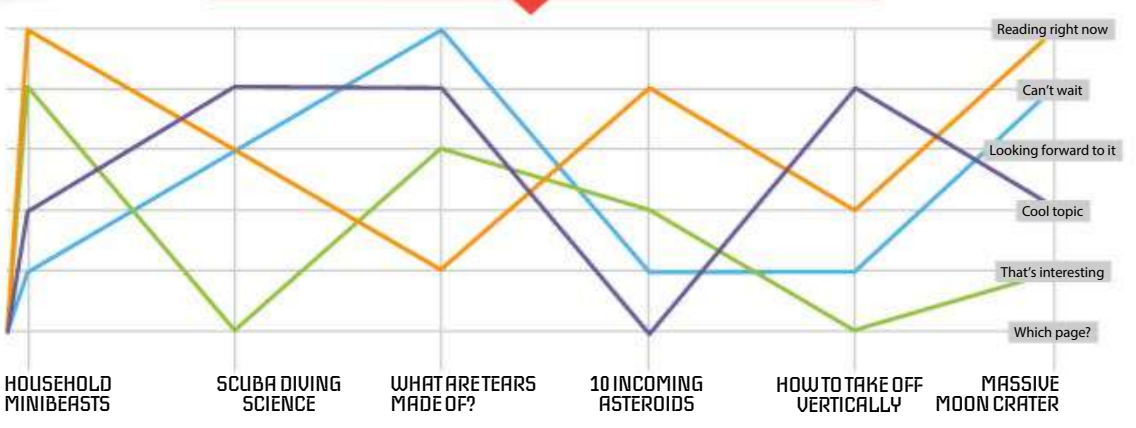
40 TERMITE FEAST
How these mini beasts turn wood to pulp

60 TELLING TIME
How sundials make use of light and shadow

71 HEAVY ARMOUR
What are bomb disposal suits made of?

SUBSCRIBE NOW
GO TO PAGE 24 FOR GREAT DEALS

WHAT WE'RE ANTICIPATING



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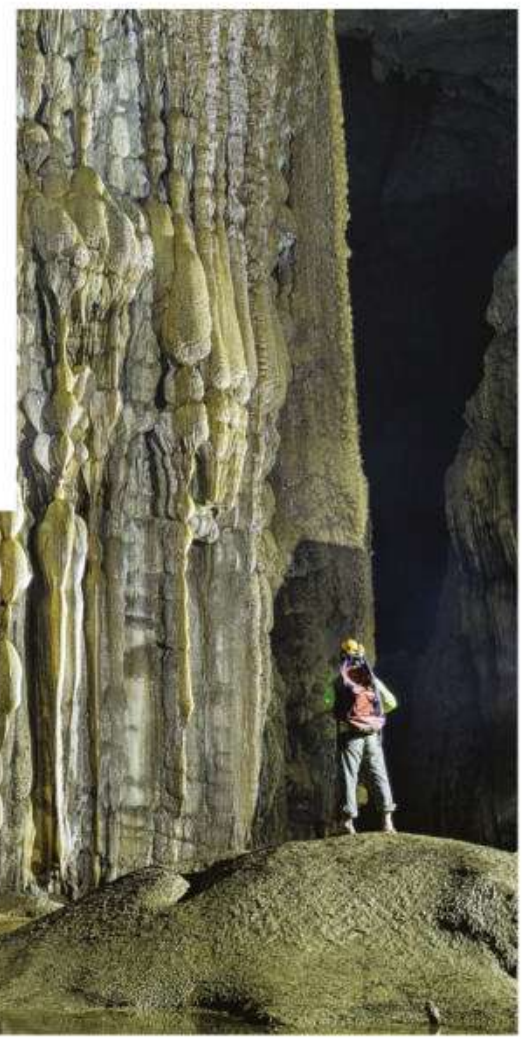
INSIDE

Issue 178



SPECIAL

26 10 Incoming asteroids
Discover the near-future encounters Earth will have with passing asteroids, some too close for comfort

SPACE

34 Massive Moon crater
The formation of Tycho, the Moon's most prominent crater

ENVIRONMENT

36 Household minibeasts
Meet the creepy critters and pesky pests that call your house 'home'

42 Why glitter is so bad for the planet
How this microplastic wreaks havoc on our bodies and the environment

44 Ten secret underground worlds
Delve deep into Earth's rock, seas and ice to discover the most stunning subsurface spectacles

50 What are horse hooves for?
These hard, living structures keep horses alive and running

HISTORY

52 Secrets of the Mary Rose
This famed Tudor ship was Henry VIII's pet project, but why did his fleet's flagship sink suddenly in the Solent?

60 How sundials tell time
These time-keeping devices can keep track of Earth's movements around the Sun

62 Isaac Newton
The pioneering physicist who got to grips with gravity and set the world in motion

TRANSPORT

64 How to take off vertically
These aircraft have ditched the runway and can fly straight up into the sky

TECHNOLOGY

68 How loudspeakers make sound
Discover how electrical currents are transformed into sound waves

70 Bomb suits explained
How this bulky armour defends against searing heat, violent explosions and flying fragments

72 Inside a fire extinguisher
These portable devices eliminate small fires before they rage out of control

SCIENCE

74 Scuba diving science
Deep dive into the physics, physiology and equipment of this popular sport

76 How CPR saves lives
Why repeated chest compressions and electric shocks can kickstart a heart

78 How do gastric bands work?
In this weight-loss procedure, surgeons tighten the stomach with a ring

80 What are tears made of?
The psychology behind crying and why our eyes water

REGULARS

06 Global eye
Science and tech news from around the world

22 Wish list
Funky Father's Day gifts

84 Braindump
Your questions answered

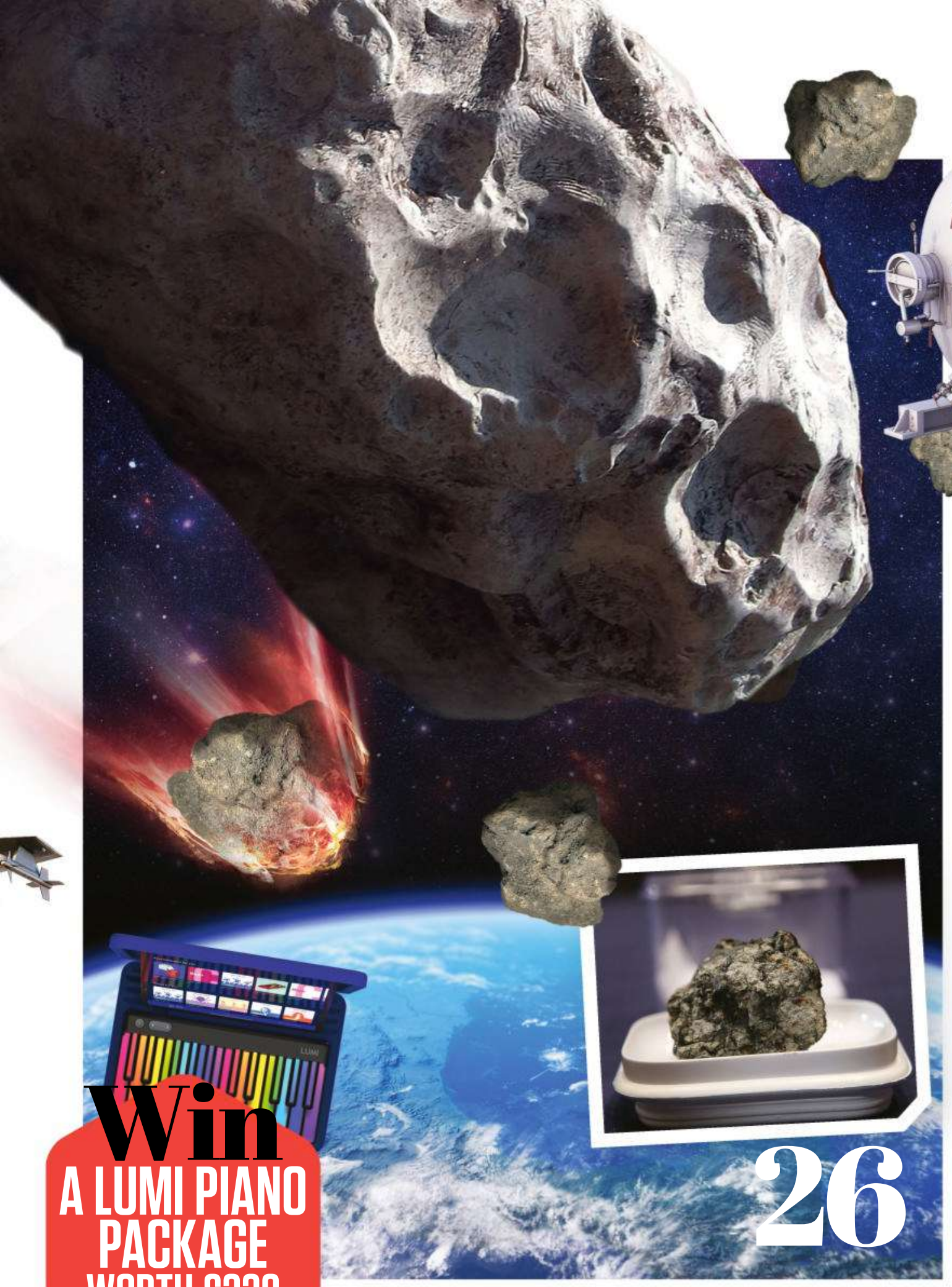
90 Book reviews

92 Brain gym
Give your brain a workout with our puzzle pages

94 How to...
Make your own cave

96 Letters
Have your say

98 Fast facts


26

74

60

76

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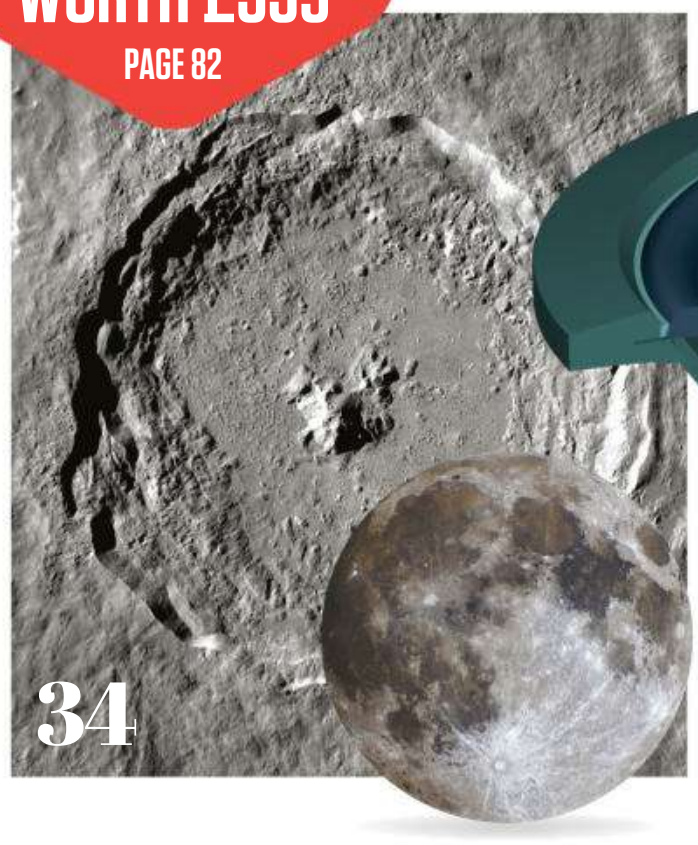
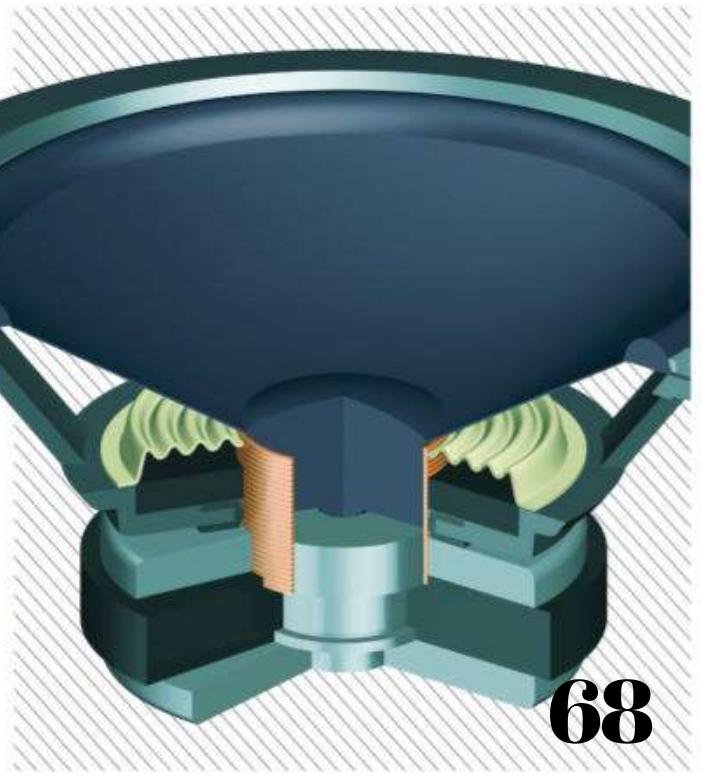
PAGE 82


34


68

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Butterfly portrait

This is a portrait of a green skipper butterfly (*Hesperia viridis*). The feather-like scales that coat the butterfly's body are modified hairs that have different roles. Some scales are responsible for releasing pheromones, while others provide pigmentation and iridescence. The scales on the insect's head allow its coiled mouthparts, called a proboscis, to extend from the head.

© Getty

Starry trail

This long-exposure composite image was snapped aboard the International Space Station by NASA astronaut Don Pettit. During its journey around Earth, the giant orbiting laboratory travels five miles per second and completes a single orbit every 90 minutes. Pettit combined 30-second exposures from a mounted camera and combined them to reveal the streaks of light left by stars.

© NASA/Don Pettit

Marble mining

Welcome to the Carrara marble mines. Located in the Apuan Alps in northern Italy, this stark quarry has been mined for this metamorphic rock for over 2,000 years. Around 60,000 tonnes of white marble is excavated each year. The mine has created marble mountains that reach a height of 1,500 metres above sea level and extend to around 1,000 metres below sea level.

© Getty

Rings around Uranus

The James Webb Space Telescope peered through the Solar System and snapped this shot of the ice giant Uranus from more than 1.6 billion miles away. Using its Near Infrared Camera, the telescope captured the planet Uranus along with six of its 27 moons – the small blue dots. The image also shows 11 of Uranus' 13 rings, some of which are so bright that they blend together, in the clearest detail to date.

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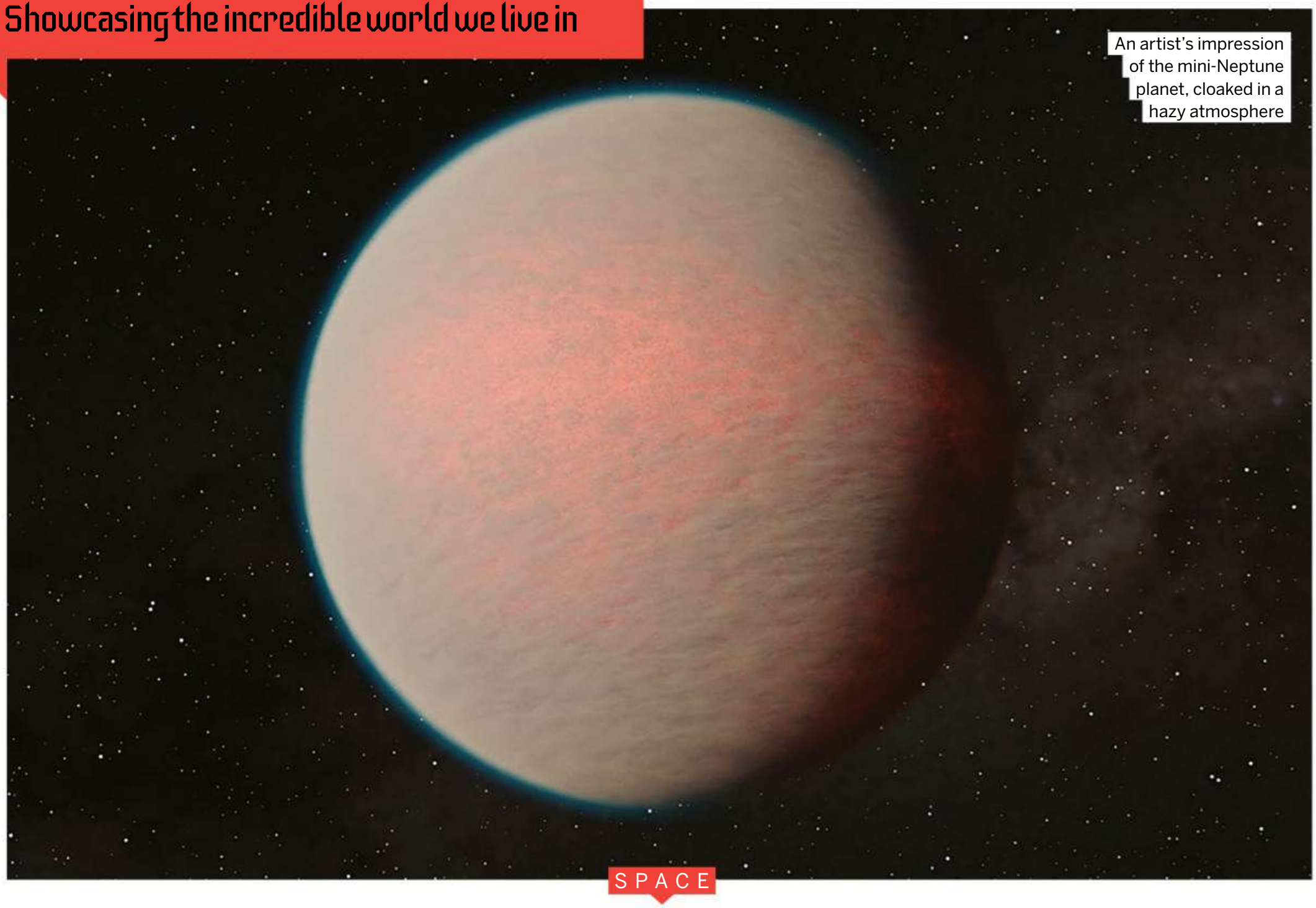


An artist's impression of the mini-Neptune planet, cloaked in a hazy atmosphere

SPACE

James Webb telescope discovers ancient 'water world'

WORDS **BRILEY LEWIS**

Astronomers have finally peered past the clouds on the exoplanet GJ 1214b, a mini-Neptune planet around a star about 40 light-years away. Mini-Neptunes, like a shrunken-down version of the familiar gas giant, are a common type of planet in our galaxy, but because there isn't one in our own Solar System, these worlds have largely remained a curiosity for scientists.

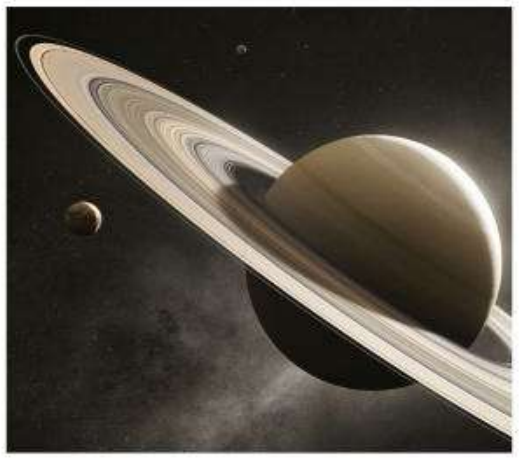
Previous observations of the distant planet were foiled by thick cloud layers, but the powerful James Webb Space Telescope's (JWST) infrared heat vision allowed astronomers to find a new view through the haze. The results reveal that GJ 1214b has an atmosphere made of steam, hinting at its past as a possible 'water world'.

"For the last almost decade, the only thing we really knew about this planet was that the atmosphere was cloudy or hazy," said Rob Zellem, an exoplanet researcher at NASA's Jet Propulsion Lab. The team used JWST's Mid-Infrared Instrument (MIRI) to map the temperature of the planet as it moved through its orbit, capturing information on both its day and night sides and enabling astronomers to figure out what it's made of.

The temperature on GJ 1214b shifted dramatically from day to night, getting as hot as 535 degrees Fahrenheit (280 degrees Celsius) and then cooling down by more than 100 degrees F at night. Imagine a day on Earth with sweltering heat during the day, and then a blizzard overnight – that's what a 100-degree difference would look like here! On GJ 1214b, this huge temperature swing indicates that the planet's atmosphere can't be just light hydrogen molecules; instead, there has to be something else, like water or methane. Researchers see this finding as an interesting clue into the planet's past, since the atmosphere doesn't match what the star is made of.

GJ 1214b "either lost a lot of hydrogen, if it started with a hydrogen-rich atmosphere, or it was formed from heavier elements to begin with, more icy, water-rich material," said Eliza Kempton, a University of Maryland astronomer. "The simplest explanation, if you find a very water-rich planet, is that it formed farther away from the host star," she added.

Astronomers still have a lot left to figure out about GJ 1214b, but they hope to observe more mini-Neptunes with JWST in the near future. They hope to figure out a consistent story for how mini-Neptunes are created, and how this particular one ended up with so much water.



An illustration of Saturn and some of its many, many moons

SPACE

SCIENTISTS DISCOVER 62 NEW MOONS AROUND SATURN

WORDS **BRANDON SPECKTOR**

Jupiter's reign as the planet with the most moons in our Solar System came crashing down as scientists confirmed the discovery of 62 new moons orbiting Saturn, bringing the ringed planet's total to 145 moons.

That's a decisive leap ahead of Jupiter's 95 confirmed moons. Saturn is now the first and only planet in the Solar System with more than 100 known moons.

A team of international researchers used data from the Canada-France-Hawaii Telescope on top of Mauna Kea, Hawaii between 2019 and 2021 by analysing sequential images taken over three-hour windows. All of the 62 newly detected moons are irregular moons, meaning they follow distant, elliptical orbits around their host planet and often move in retrograde, or in the opposite direction of Saturn's rotation. Many of them clump together, suggesting they may have originated from a parent moon that broke apart millions of years ago.

"As one pushes to the limit of modern telescopes," said Brett Gladman, a professor of astronomy and astrophysics at the University of British Columbia, "we are finding increasing evidence that a moderate-sized moon orbiting backwards around Saturn was blown apart something like 100 million years ago."

PLANET EARTH

Energy of "25 billion atomic bombs" trapped on Earth in 50 years

WORDS **HARRY BAKER**

Global warming has trapped an explosive amount of energy in Earth's atmosphere in the past half century, the equivalent of about 25 billion atomic bombs, a new study finds.

An international group of researchers estimated that between 1971 and 2020, around 380 zettajoules (380,000,000,000,000,000,000,000 joules of energy) have been trapped by global warming.

Such a big number is hard to put into context, but two researchers who were not involved in the study have put it into perspective by comparing the energy to that released by nuclear bombs. However, even then, the amount is still hard to wrap your head around.

Did you know?

The Nagasaki nuke was bigger than the bomb dropped on Hiroshima

Researchers calculated that 380 zettajoules is equivalent to around 25 billion times the energy released during the detonation of 'Little Boy', the atomic bomb dropped on Hiroshima, Japan, on 6 August 1945.

Even more mind-blowing is that the energy absorbed by the planet during this time period likely equates to only around 60 per cent of total greenhouse gas emissions, so the actual number is even higher.

But such a large amount of energy is puzzling, because based on that heat being trapped in the atmosphere, average global temperatures should have risen by dozens of degrees since preindustrial times, rather than the 1.2 degrees Celsius we have observed. So where has this extra energy gone?

According to the study, the oceans have absorbed around 89 per cent of the energy (338.2 zettajoules), land has absorbed six per cent (22.8 zettajoules), four per cent (15.2 zettajoules) has melted parts of the cryosphere, the part of Earth's climate system that includes snow, sea ice, freshwater ice, icebergs, glaciers and ice caps, ice sheets, ice shelves and permafrost, and just one per cent (3.8 zettajoules) has remained in the atmosphere.

The majority of the heat absorbed by the seas is trapped in the upper 0.6 mile of the oceans. This has spared humanity from the brunt of climate change so far, but it has also caused massive increases in sea surface temperatures, which has accelerated polar melting, damaged marine ecosystems, increased the severity of tropical storms and begun to disrupt ocean currents.

However, the oceans will not protect our planet forever, so we must begin rapidly decreasing greenhouse gas emissions by decarbonising the global economy to ensure our future survival.

An artist's interpretation of an atomic bomb detonating

© Alamy / Getty / NASA/JPL-Caltech/R. Hurt (IPAC)

A female Yangtze giant softshell turtle at Suzhou Zoo in Suzhou, China. Not the female caught in 2020

Did you know?

The oldest known species of turtle dates back 120 million years

ANIMALS

Turtle species doomed to extinction after last female found dead

WORDS HARRY BAKER

The Yangtze giant softshell turtle (Rafetus swinhoei), the world's largest freshwater turtle and one of the most endangered species on Earth, is now essentially doomed to extinction after the last known remaining female washed up dead in Vietnam.

The female turtle, which was around 1.5 metres long and weighed 93 kilograms, was discovered dead on 21 April on the shores of Dong Mo Lake in Hanoi's Son Tay district. The turtle likely died several days earlier, but the cause of death is still unknown.

This female Yangtze giant softshell turtle was discovered in October 2020. At the time, no other female Yangtze giant softshell turtles were known to exist; the last known female died after a failed attempt at artificial insemination at Suzhou Zoo, China in April 2019.

When the dead turtle was discovered last month, conservationists hoped that it belonged to another unknown female, and that the known female might still be alive. But experts have now confirmed this is not the case.

"It is the same individual that we've been monitoring in recent years," Tim McCormack, director of the Asian Turtle Program for Indo-Myanmar Conservation, told *TIME* magazine. "It's a real blow."

There are now just two known R. swinhoei males left in existence: one in Suzhou Zoo and another that still resides in Dong Mo Lake.

Researchers had hoped that the female and male in Dong Mo Lake would eventually mate and produce a clutch of eggs. Based on its size, the female was likely several decades old, meaning it was probably sexually mature.

"It was a large female that obviously has great reproductive capacity," McCormack said. "She could have potentially laid 100 eggs or more a year." However, the pair never mated, even though researchers built an artificial nesting beach at the lake for the female to lay her eggs if she ever needed it.

Yangtze giant softshell turtles, also known as Hoan Kiem turtles and Swinhoe's softshell turtles, were once abundant in the Yangtze River in China and the surrounding freshwater ecosystems, like Dong Mo Lake. However, humans hunted the turtles for their meat, and they have lost most of their natural habitat.

There is a chance that other males and females may be found in the future. After all, this female did evade detection for years. But if another female cannot be found in the wild, R. swinhoei will eventually become the latest name on a growing list of species that have been wiped out by humans.

ARCHEOLOGY

1ST-CENTURY BURIAL HOLDS MEDICAL TOOLS OF A ROMAN DOCTOR

WORDS TOM METCALFE

The grave of a medical man who died roughly 2,000 years ago has been unearthed in Hungary, along with needles, forceps, scalpels and other tools he used for his profession.

Dating from the 1st century AD, this is a rare find, according to a statement by Eötvös Loránd University (ELTE) in Budapest. "It is striking in itself that a doctor equipped with such prestigious equipment visited this area," which the Romans called 'barbarian' – their term for anywhere outside their territories. "The current assumption is that the well-equipped doctor, probably trained in one of the Imperial centres, may have travelled to this area to save someone," the ELTE said.

The tools were found in two wooden chests at the foot of the grave; they include pliers, needles, forceps and scalpels for surgical procedures.

The scalpels are made of a copper alloy decorated with silver, and have removable steel blades. The excavators found a grinding stone that was used to sharpen the blades and possibly to mix medical herbs.

The archaeologists also recovered the near-complete skeleton of the 'doctor' himself, which showed he was about 50 or 60 years old when he died, but who had suffered from no obvious illnesses or trauma.

Archaeologists think the physician may have been travelling beyond the frontiers of the Roman Empire to treat patients

The bulbous-eyed mudskipper could offer key clues about how our fishy ancestors

PLANET EARTH

Blinking fish could hold secrets of our evolution

WORDS BEN TURNER

An ugly blinking fish could hold the secret to how ancient animals evolved the ability to live on land, a new study has found.

Mudskippers, a subfamily of fish that live both on land and in the water, are the only fish that can blink, and they evolved this ability independently from our ancestors, a concept known as convergent evolution.

Scientists think that blinking evolved in land animals when they made the transition from the oceans roughly 375 million years ago. Therefore, studying this example of convergent evolution has offered clues as to how our primordial ancestors first took to Earth's shores.

"Animals blink for many reasons," said Thomas Stewart, an assistant professor of biology at Penn State University. "It helps us keep our eyes wet and clean, it helps us protect our eyes from injury, and we even use blinking for communication.

"Studying how this behaviour first evolved has been challenging because the anatomical changes that allow blinking are mostly in soft tissues, which don't preserve well in the fossil record," he added. "The mudskipper, which evolved its blinking behaviour independently, gives us the opportunity to test how and why blinking might have evolved in a living fish that regularly leaves the water to spend time on land."

To study the blinking of the mudskipper, the researchers filled a tank with high-speed cameras to see how they moved between the water and the shore, and in which locations the fish blinked. While submerged, the mudskippers barely blinked at all, but when in the air, they blinked often. When the researchers increased the airflow and rate of evaporation in the tank, the mudskippers began blinking more frequently.

"We found that, just like humans, mudskippers blink more frequently when confronted with dry eyes," said Brett Aiello, an assistant professor of biology at Seton Hill University. "What's incredible is that they can use their blinks to wet their eyes, even though these fish haven't evolved any tear glands or ducts. Whereas our tears are made by glands around our eyes and on our eyelids, mudskippers seem to be mixing mucus from the skin with water from their environment to produce a tear film."

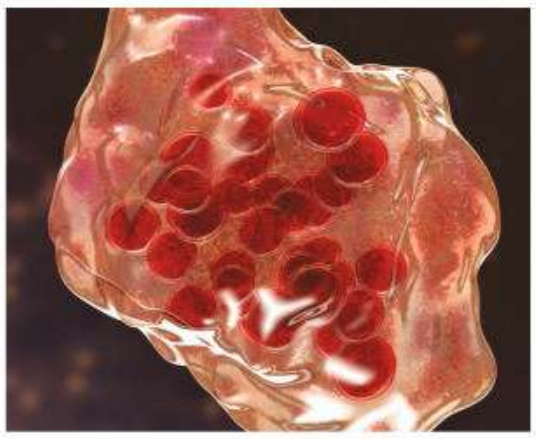
To understand how the fish evolved the ability to blink, as well as retrieve clues on how our fishy ancestors did the same, the researchers compared the mudskipper's anatomy with those of close relatives that don't blink. They found that the creatures' eyes had evolved to rest above a socket covered in a stretchy membrane called a dermal cup, and that they were sucked downward into this cup to conduct the blink, which lasts about as long as a human's blink.

The muscles that performed this blinking action are not new, but rather a simple rearrangement of existing ones. Therefore, the researchers think ancient fish likely didn't need complex adaptations to begin blinking. Instead, the fish probably achieved this feat thanks to a shuffling of their rudimentary biology.

"Based on the fact that mudskipper blinking, which evolved completely independently from our own fishy ancestors, serves many of the same functions as blinking in our own lineage," said Stewart, "we think that it was likely part of the suite of traits that evolved when tetrapods were adapting to live on land."

© Getty / ELTE Faculty of Humanities

GLOBAL EYE



Maine recently reported a potential measles case in a child in the state

HEALTH

MAINE SEES ITS 1ST MEASLES CASE IN FOUR YEARS

WORDS **NICOLETTA LANESE**

A child in Maine who recently tested positive for measles may be the state's first case of the viral infection since 2019, the Maine Department of Health and Human Services (DHHS) reported on 5 May.

While the case still needs to be confirmed by the federal Centers for Disease Control and Prevention (CDC), "out of an abundance of caution," Maine's public health agencies are assuming the child is infectious and working to identify and contact people who may have been exposed.

The CDC recommends that children receive their first dose of the MMR vaccine, which guards against measles, mumps and rubella, between 12 months and 15 months old. Children should get their second dose between four and six years old. Alternatively, the MMRV vaccine, which also guards against varicella (chickenpox), may be given following the same vaccination schedule.

One dose of either vaccine is roughly 93 per cent protective against measles, and two doses are 97 per cent protective, meaning there's a small chance of infection even after two doses. However, vaccinated individuals tend to have much milder cases of the disease than unvaccinated people do.

The Maine child with a positive measles test had received one dose of a measles vaccine.

TECH

China rover may have found evidence of recent water on Mars

WORDS **JOANNA THOMPSON**

Mars may have had liquid water on its surface as recently as 400,000 years ago, data from China's Zhurong rover suggests.

Researchers used three of the craft's instruments to sample sand dunes from Mars' Utopia Planitia, a low-lying region in the northern hemisphere. In the region's distinct, salty cracks, researchers believe they have found trace evidence of water from much more recently than previously discovered.

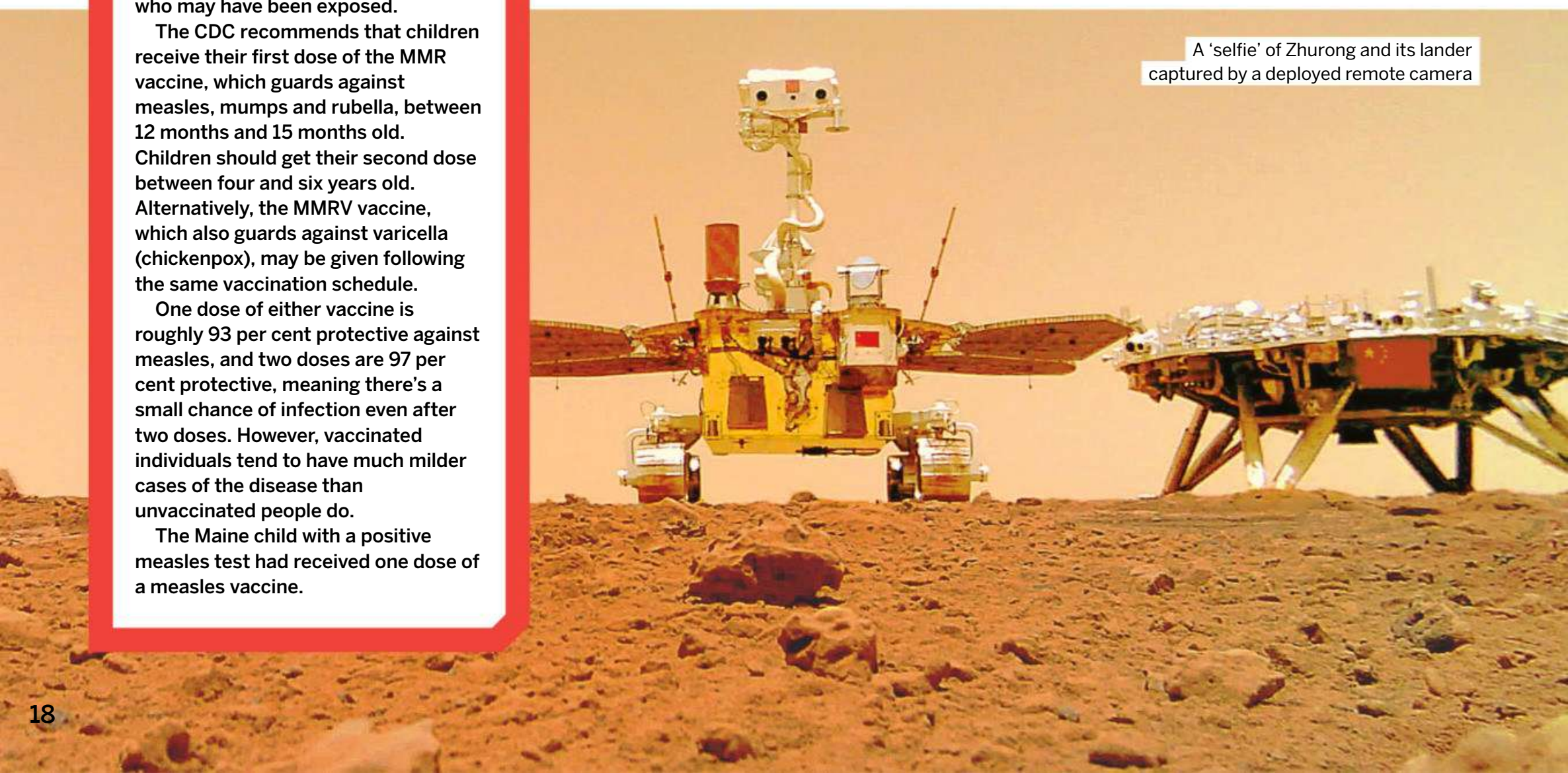
"We inferred that these dune surface characteristics were related to the involvement of liquid saline water formed by the subsequent melting of frost/snow falling on the salt-containing dune surfaces," said Qin Xiaoguang, a geophysicist at the Chinese Academy of Sciences.

Scientists have been searching for water on Mars since the late 1800s, when some astronomers mistakenly believed they had spotted 'canals' criss-crossing the surface of the Red Planet. Since then, data from various probes, rovers and spectroscopic tools have revealed that a small amount of frozen water exists on the Martian surface at its polar ice caps and inside craters. Researchers believe that the rest of the planet dried up billions of years ago.

But Qin's team's findings could overturn that notion. They determined that patterns of ridges and fissures on Utopia Planitia are most likely the result of thawing snow or frost. What's more, based on the weathering and cratering rate of Mars' surface, the researchers believe that the features formed between 1.4 million to 400,000 years ago. To put that into perspective, the first modern humans (homo sapiens) are thought to have evolved around 300,000 years ago, meaning that our early ancestors, such as Homo erectus, may have walked on Earth while water flowed on Mars.

Zhurong landed on Mars in May 2021 and has covered nearly 1.2 miles since then. The rover has been silent since May 2022 when it entered hibernation mode in order to save power over the Martian winter. The team believes that a layer of dust covering its solar panels has since prevented it from waking up. This is not an uncommon end for robots on Mars; a similar fate befell NASA's InSight rover in December 2022.

However, Zhurong has continued to send valuable data back to Earth. It could even help inform future searches for microbes on Mars, which based on Zhurong's findings would likely need to be adapted to very salty environments.



A 'selfie' of Zhurong and its lander captured by a deployed remote camera

Did you know?

48,500 year-old viruses have been found, frozen in permafrost

Mirusviruses regulate the activity of plankton and contribute to the health of the marine ecosystems

PLANET EARTH

Never-before-seen viruses discovered in the oceans

WORDS SASCHA PARE

Scientists have discovered never-before-seen viruses that thrive in sunlit oceans from pole to pole and infect plankton. They dubbed the newfound microbes 'mirusviruses', 'mirus' meaning 'strange' in Latin.

The researchers concluded that mirusviruses belong to a large group of viruses called Duplodnaviria, which includes the herpesviruses that infect animals and humans, based on shared genes that encode the shell, or particle enclosing their DNA. But the strange newfound viruses also share a staggering number of genes with a group of giant viruses, called Varidnaviria.

This suggests that mirusviruses are a bizarre hybrid between two distantly related viral lineages, the scientists concluded. "They seem to be an extremely unusual group of viruses," said Tom Delmont, a researcher at the French National Centre for Scientific Research (CNRS). "This is why we consider them as being chimeric, because they are a mix of two different groups of viruses – on one side, the herpesviruses, based on the particle genes, and on the other side, the giant viruses, based on many more genes." The discovery of the viruses highlights how little we know about the viruses lurking in Earth's oceans.

To find them, the team pored over data from the Tara Ocean expedition, which collected nearly 35,000 ocean water samples containing viruses, algae and plankton between 2009 and 2013. The researchers then searched for evolutionary clues in millions of microbes' genes. "Working on this data is like surveying a huge area of sand with a metal detector," Delmont said. "We found an evolutionary treasure."

In combing through this data trove, the scientists detected a previously undescribed lineage of double-stranded DNA viruses, the mirusviruses, that can be found in the sunlit surface waters of polar, temperate and tropical oceans. These abundant viruses infect plankton, which are tiny organisms that drift on ocean currents and can produce spectacular blooms visible from space.

By invading the plankton's cells, mirusviruses likely help regulate the microorganisms' activity and thus the flow of carbon and nutrients through the ocean.

"Viruses are a very natural component of plankton at the surface of the ocean. They are going to destroy many, many cells every day and this is going to release nutrients, particles inside the cells that are going to be used by other cells to be active and healthy."

Mirusviruses may be the key to resolving the enigmatic origin of herpes viruses. The genes encoding the protective shell around viral DNA are strikingly similar in both groups, suggesting that they are related.

"This means there is a shared evolutionary history between herpes, that infect only animals, and the mirusviruses that are everywhere in the ocean, where they infect unicellular organisms," Delmont said. "All of this is pointing to a planktonic origin for herpes."

These unusual viruses represent a new front for research into microbial life in our oceans, and there are many more discoveries. "We will be trying to isolate mirusviruses in the coming year," said Hiroyuki Ogata, a professor at the Institute for Chemical Research at Kyoto University. "Isolation is now essential to uncover the mystery of this new viral [group]."

© Getty / Alamy

HEALTH

Non-sugar sweeteners don't help with weight loss

WORDS **CHRISTOPH SCHWAIGER**

Non-sugar sweeteners (NSS) shouldn't be used to reduce body weight, according to newly released guidance from the World Health Organisation (WHO). The United Nations (UN) health agency's report also suggested that long-term use of such sweeteners may come with health risks.

Announced on 15 May, the new recommendations are based on a systematic review of evidence. The review includes more than 280 studies of both low- and no-calorie synthetic sweeteners, like aspartame, and natural extracts, like stevia. The findings suggest that using NSS in place of sugar does not have any long-term benefits in reducing body fat in either adults or children.

The review also suggests that long-term use of these sweeteners may be linked to a slightly increased risk of type 2 diabetes, cardiovascular diseases and early death from any cause in adults.

However, the WHO noted that the evidence of links between long-term NSS use and risk of disease or early death isn't strong enough to be conclusive, in part due to the complicated patterns of NSS use and underlying characteristics of the study participants that may have confounded the review's results. Because of this, the WHO labelled its recommendation as "conditional", meaning there's still uncertainty about the benefits of implementing it.

"Replacing free sugars with NSS does not help with weight control in the long term," said Dr. Francesco Branca, WHO director of nutrition for health and development. "People need to consider other ways to reduce free sugars intake, such as consuming food with naturally occurring sugars, like fruit, or unsweetened food and beverages."

The WHO said that its guidance on sweeteners applies to everyone, except for people with existing diabetes. Moreover, the recommendations don't apply to medications and personal care products like toothpaste that may contain small amounts of sweeteners that are added to make them more palatable.

In its review, the health agency looked into studies that compared body weights of people consuming regular sugars with those consuming sweeteners. The reviewed randomised control trials, gold-standard trials with a placebo group for comparison, suggest that in the short term, replacing your sugar intake with NSS may decrease your weight without affecting your cardiovascular or metabolic health.

However, long-term observational studies suggest that consuming sweeteners over a long period of time is linked to higher likelihood of obesity and body mass index (BMI), an indirect estimate of body fat, as well as increased risk of certain diseases and early death.

People who don't consume much sugar in the first place aren't likely to have any weight-loss benefits if they switch to sweeteners, the WHO guidelines noted. They'll "likely only be subjected to the potential undesirable effects of NSS use," the WHO said.

The WHO assessed the overall certainty of the evidence it reviewed as low. The agency called for further research to determine which mechanisms the NSS are involved with that might have negative effects on human health.

Nonetheless, the health organisation said that because plausible mechanisms for these adverse effects have been identified and validated in animals, the potential links between NSS and human disease should be taken seriously.

Sugar substitutes, or non-sugar sweeteners, don't seem to help with long-term weight control, WHO reports

An artist's illustration of the pliosaur, an ancient ambush predator twice the size of an orca

ANIMALS

"Truly gigantic" Jurassic sea monster discovered by chance in museum

WORDS **BEN TURNER**

The fossilised remains of a "truly gigantic" ancient sea monster have been discovered by chance in an English museum, revealing one of the largest carnivores to ever stalk the seas.

The four bones are vertebrae from an unknown species of Jurassic predator called a pliosaur and show that the dagger-toothed creatures could grow almost 15 metres long – twice the size of an orca (Orcinus orca). The new finding drastically revises previous estimates for the scale of the prehistoric monsters.

"It's wonderful to prove there was indeed a truly gigantic pliosaur species in the Late Jurassic seas," said David Martill, a professor of palaeobiology at the University of Portsmouth. "It wouldn't surprise me if one day we find some clear evidence that this monstrous species was even bigger."

Martill came across the bones while looking through fossil drawers at Abingdon County Hall Museum in the UK. After encountering a large vertebra, he was informed by the museum's curator that three more were in storage. The fossils, which come from the Kimmeridge Clay Formation, were discovered during excavations at Warren Farm in Oxfordshire. They were unearthed from a deposit dated to around 152 million years ago during the late Jurassic.

By laser-scanning the fossils, Martill and his colleagues estimated they belonged to a fearsome sea monster that stretched from 9.8 to 14.4 metres long, making it the largest pliosaur ever discovered. Prior to this, one of the largest known pliosaurs was Kronosaurus (Kronosaurus queenslandicus), which grew to between 10 to 11 metres long.

Did you know?

Livyatan is an extinct marine predator the size of a sperm whale

Pliosaurs were the ocean's biggest predators during the Jurassic period (201 to 145 million years ago). They stalked the seas using four powerful, paddle-like flippers. Pliosaurs were likely ambush predators, leaping out at prey from deep and dark water and impaling them with dagger-sharp teeth, before crushing them with a bite more powerful than a Tyrannosaurus rex's.

"We know these pliosaurs were very fearsome animals swimming in the seas that covered Oxfordshire 145-152 million years ago," Martill said. "They were at the top of the marine food chain and probably preyed on ichthyosaurs, long-necked plesiosaurs and maybe even smaller marine crocodiles, simply by biting them in half and taking chunks off them."

SPACE

Astronomers find remnants of the oldest stars in the universe

WORDS **JOANNA THOMPSON**

Astronomers may have found the remnants of some of the universe's first stars. The chemical signatures of these faraway, 13-plus-billion-year-old objects are remarkably different from those of younger stars, like our Sun. By studying them, scientists hope to shed light on how stars, galaxies and even basic elements form.

In the early days of the universe, only simple elements such as hydrogen and helium were available. The first stars ignited from these elements. Over time, their white-hot cores cooked atoms into heavier elements, such as carbon, oxygen, magnesium and eventually metals. Today, most of the stars scientists observe are rich in metals like iron.

Using the European Southern Observatory's Very Large Telescope (VLT), researchers peered into three distant clouds of gas. On their own, these wouldn't tell scientists much, but light from nearby quasars helped reveal the cloud's secrets. Based on which wavelengths of light the clouds absorbed, the team determined what elements the remains were made of.

The clouds were extremely poor in iron and other metallic elements, but rich in carbon, oxygen and magnesium – precisely what would have been left over after the first stars ran out of fuel and exploded.

This artist's impression shows a gas cloud containing different chemical elements

© Getty / ESO/L. Calçada, M. Kornmesser

WISH LIST

Perfect gifts for FATHER'S DAY

OONI KODA

WWW.OONI.COM £349 (APPROX $440)

The Ooni Koda pizza oven is a great gift for any foodie dads this Father's Day. As part of its range of portable pizza ovens, Ooni has created a gas-powered oven to stone-bake a pizza in just 60 seconds. After the Ooni Koda is ignited, it takes only 15 minutes to reach temperatures of up to 500 degrees Celsuis, which you can set using its control dial. Although there's not much that can beat a freshly cooked pizza, the Ooni Koda can also be used to roast fish and vegetables, and even cook steaks. It only weighs 9.25 kilograms and is completely portable – perfect for outdoor gatherings or as an addition to your summer barbeque.

SENSE 2

WWW.FITBIT.COM £269.99 (APPROX $341)

If your father's a fan of health and wellbeing and wants to keep track of his progress, then the Sense 2 by Fitbit might be the perfect gift. This intuitive smartwatch is jam-packed with statistics to pore over, including sleep logs, breathing rates, skin temperature and heart health. It comes with a stress management feature that uses 'body-response tracking' to help you manage stress through guided breathing, exercise and meditation. Along with all the bells and whistles of a typical smartwatch, such as texting options, Google Wallet and Google Maps, the Sense 2 has Amazon Alex built in, so you can set alarms and check the weather with ease.

MARSHALL ACTION III

WWW.MARSHALLHEADPHONES.COM

£259.99 /(APPROX $328)

For music-loving dads, the Marshall Acton III is a great gift that combines style with excellent sound quality. This Bluetooth speaker uses intuitive features, such as Dynamic Loudness, to adjust the balance of your music for outstanding sound at every volume. The sound produced by this compact speaker quickly fills the entire room, allowing you to immerse yourself in the music. The set for the ACTION III is quick and easy to pair with your smartphone. Marshall has also ensured that the ACTION III is PVC-free and made from 70 per cent recycled plastic.

GARMIN DASH CAM™ MINI 2

WWW.GARMIN.COM

£119.99 (APPROX $151)

The Mini 2 has an impressive 140-degree field of vision and can capture details on roads using a 1080-pixel high-definition camera. Once the camera is plugged in, it automatically begins recording, which you can access at any time for a live view from your windscreen.

In the event of a collision, the Mini 2 will automatically save time just before, during and after the inserted microSD card. For an additional monthly fee, the Mini 2 can automatically upload footage of an incident to an online storage vault, via the Garmin Drive™ app, for 24 hours or more.

3 IN 1 WIRELESS CHARGING STATION

WWW.JOURNEYOFFICIAL.CO.UK

£89.99 (APPROX $114)

Ensure your dad's Apple devices are always fully charged with the three-in-one wireless charging station by Journey. This handy bedside table gadget can simultaneously charge an iPhone 12, 13 or 14; Apple Watch and AirPods wirelessly. The Journey charging station comes with over-current, over-voltage and over-temperature protection to prevent damage to your devices. The magnetic mount of this charging station doubles as a stand that allows you to alter the position of your smartphone so you can stream your favourite shows while also charging.

ATOM SE DRONE

WWW.POTENSIC.COM £300 (APPROX $379)

Reach new heights with the ATOM SE drone by Potensic. This lightweight drone, weighing around 249 grams, is small enough to easily fit in the palm of your hand when folded up. The control range for the ATOM SE can reach up to around 2.5 miles using your smartphone and controller accessories. It also comes with three flight modes: video, normal and sport, topping speeds of up to 16 metres per second. The ATOM E boasts a 4K-resolution video camera, capturing at 30 frames per second for low-latency high-quality aerial footage. During flight, the onboard battery can keep the drone aloft for up to 31 minutes on a single charge.

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HOW IT WORKS
INSIDE A VERTICAL TAKE-OFF & LANDING JET
HOW CPR SAVES LIVES
10 INCOMING ASTEROIDS
HOW WE TRACK AND INVESTIGATE THE BIGGEST SPACE ROCKS HEADING EARTH'S WAY
WHAT HORSE HOOVES ARE FOR
GASTRIC BANDS EXPLAINED
WHAT'S THAT BIG MOON CRATER?
WHY DO WE CRY?
THE PROTECTIVE POWER OF BOMB SUITS
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SPECIAL

10 INCOMING ASTEROIDS

Discover the near-future encounters Earth will have with passing asteroids – some more hazardous than others

WORDS **ANDREW MAY**

DID YOU KNOW? Asteroid Day marks the anniversary of a major impact event that occurred in Siberia on 30 June 1908

As scary as an incoming asteroid may sound, it doesn't have to mean the end of the world. It's true space rocks sometimes collide with our planet, as happened with devastating effect 66 million years ago when a massive impact wiped out the dinosaurs. But such events are the exception rather than the rule. By astronomical standards, Earth is a very small target. Asteroids move on precisely determined orbits, so the vast majority of them simply whiz past the planet at a safe distance. Such encounters are a good thing for astronomers because they give them a chance to study asteroids at close range, and these small, rocky objects can tell us a lot about the origin and evolution of the Solar System. When the first asteroids were discovered, they were all found to lie in an "asteroid belt' between the orbits of Mars and Jupiter. It's still true today that most known asteroids are located in this region.

Asteroids can be thought of as miniature planets, a few metres to several thousand metres in size, which move on a range of orbits around the Sun in much the same way planets do. All these orbits have a similar basic shape: a kind of distorted circle called an ellipse. The point on the ellipse that's furthest from the Sun is called aphelion, while the closest is perihelion. In the case of a planet like Earth, the difference between perihelion and aphelion is very small, which means that the orbit is almost circular. Asteroid orbits, on the other hand, can be much more eccentric than this, and some of them can actually have a perihelion inside Earth's orbit and an aphelion outside it. In other words, their orbits around the Sun overlap with our own planet's.

© Getty

ASTEROID TYPES

Asteroids vary in their chemical composition, but these are the three most common types

C-TYPE

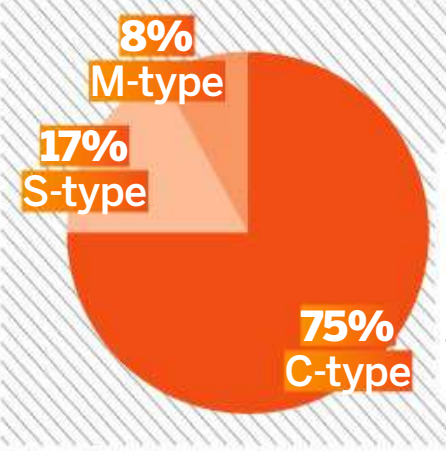
C stands for carbonaceous or chondrite, and these asteroids are relatively dark in appearance. Although they're the most common type of asteroid, they're more typically found in the outer parts of the asteroid belt rather than close to Earth.

S-TYPE

S stands for stony or silicate, and these asteroids are brighter in appearance than C-types. They become more common in the inner parts of the asteroid belt and account for the majority of near-Earth asteroids.

M-TYPE

M stands for metallic, and these asteroids are mainly composed of a nickel-iron mixture. They're mostly found in the middle of the asteroid belt, and despite their comparative rarity would be a particularly attractive target for asteroid mining.



These three compositions account for most of the known asteroid types in the Solar System

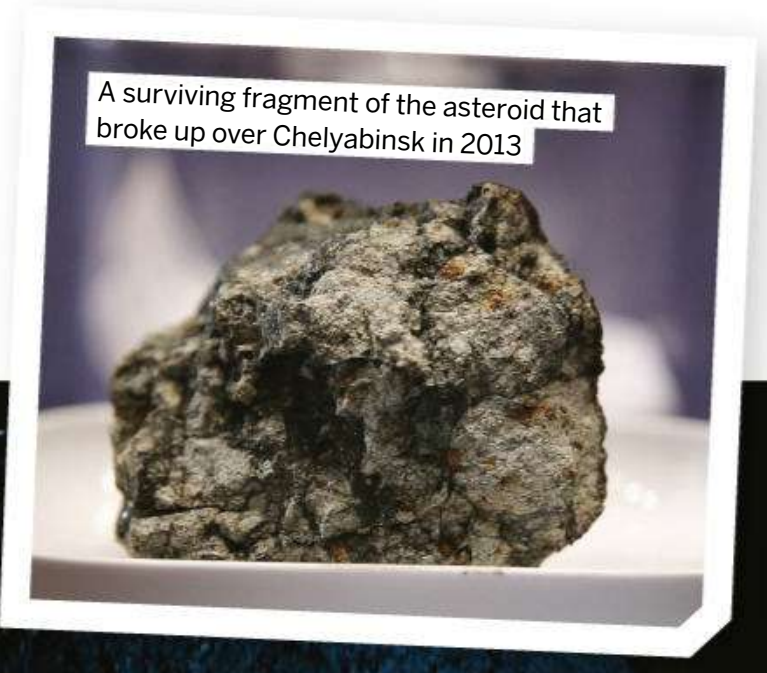
NASA defines a near-Earth asteroid (NEA) as one that has a perihelion distance of less than 1.3 astronomical units (AU) – in other words, less than 30 per cent further out from the Sun than Earth's orbit. Actual Earth-crossing asteroids – ones that have a perihelion inside our orbit and an aphelion outside it – are divided into two families, Apollos and Atens, with a subtle distinction between the two. Apollo asteroids spend most of their time outside our own orbit, only venturing inside it when they're close to perihelion, while Atens follow the opposite pattern. They spend most of their time inside our orbit, and only cross outside of it when they're close to aphelion.

There are also two other types of NEA that don't actually cross Earth's orbit but still come within the specified distance of 0.3 AU of it. The Atira family always remains just inside our orbit, while the Amors are always just outside it. These two asteroid types don't pose a collision risk to our planet at present, but they might do at some point in the future. That's because asteroid orbits can change over the course of many years due to the gravitational pull of Earth and the other planets as they pass near them.

Did you know?

Apophis was an evil demon in Egyptian mythology

The fact that an asteroid's orbit crosses Earth's doesn't automatically mean there's a collision risk, since the two orbits might be inclined at different angles. A further criterion is required to distinguish a potentially hazardous asteroid



A surviving fragment of the asteroid that broke up over Chelyabinsk in 2013

99942 APOPHIS

Diameter: **370 metres**
Composition: **S-type**
Orbit type: **Aten**

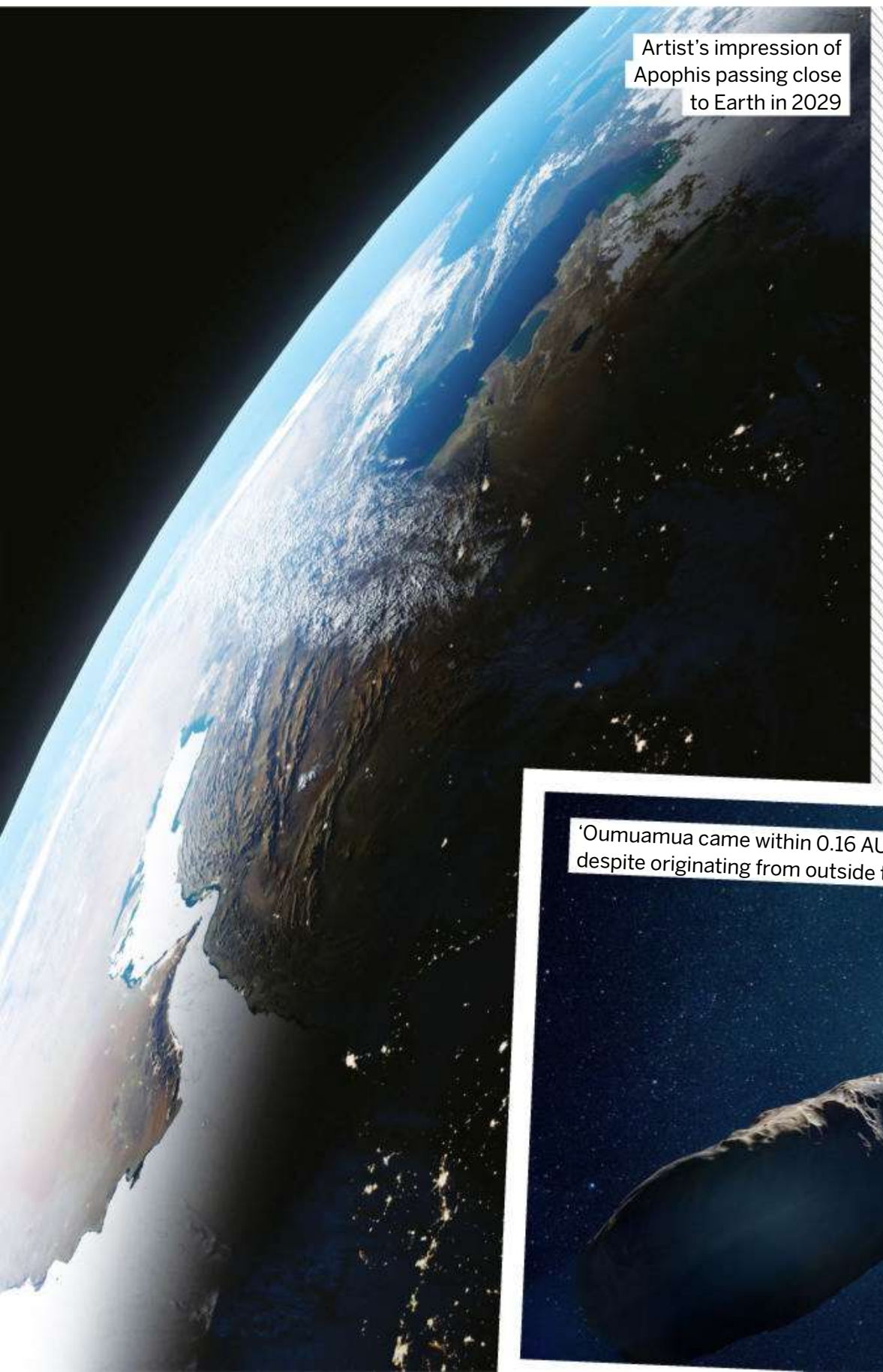
Of all the known near-Earth asteroids, Apophis is the one that will come closest to hitting our planet in the foreseeable future. This will happen on 13 April 2029, when Apophis will whiz past around 20,000 miles above Earth's surface. Astronomers have measured its orbit so accurately that they can say with certainty that there's zero chance of an actual collision.

DID YOU KNOW? NASA's Psyche mission, due to launch later in 2023, will visit a metal-rich M-type asteroid

2001 WN5

Diameter: **932 metres** Composition: **Unknown** Orbit type: **Apollo**

Based on currently available data, this will be the next asteroid of significant size – it's almost a thousand metres in diameter – to make a close pass of Earth. This will occur on 26 June 2028, with a closest point of approach of just under 155,000 miles – around two-thirds of the distance to the Moon. It's possible the asteroid will become bright enough to be visible through binoculars.



Artist's impression of Apophis passing close to Earth in 2029

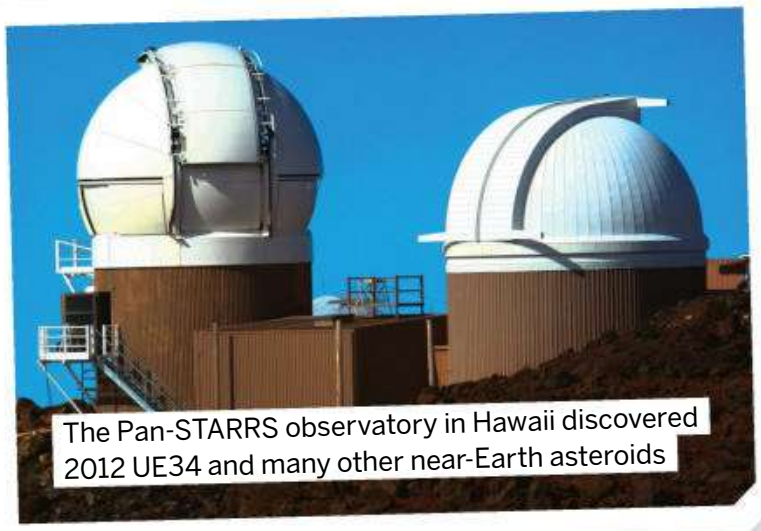
2005 YU55

Diameter: **360 metres**
Composition: **Likely S-type**
Orbit type: **Apollo**

This asteroid made a close pass of Earth – at around 202,000 miles – on 8 November 2011, when NASA took the opportunity to study it carefully using a radar imaging system at Goldstone in California. The asteroid will make a similarly close pass in January 2029... not of Earth on that occasion, but of Venus. Its next close encounter with our planet won't be until November 2075, when it will come slightly closer than it did in 2011.

'Oumuamua came within 0.16 AU of Earth in 2017, despite originating from outside the Solar System

© Alamy / Getty / NASA



The Pan-STARRS observatory in Hawaii discovered 2012 UE34 and many other near-Earth asteroids

(PHA) from a non-hazardous one. The main requirement here is that it comes within 0.05 AU of Earth's orbit, or approximately 4.65 million miles – that's roughly 20 times the distance from Earth to the Moon. A further criterion is that, to be classed as a PHA, an asteroid has to be larger than 140 metres in diameter. Objects smaller than this are much less likely to cause serious damage.

Fortunately for us, small asteroids are far more numerous than large ones. The huge space rock that killed off the dinosaurs was between six and ten miles in size – but that was 66 million years ago, which shows how rare such occurrences are. Far more common are asteroids that are just a few tens of metres across, such as the one that entered Earth's atmosphere over Chelyabinsk in Russia in 2013. That one was the size of a six-storey building, and resulted in little damage beyond a lot of broken windows and minor cuts and grazes to people on the ground.

In the case of the great majority of asteroids that skim past Earth without hitting it, the resulting close encounters provide valuable opportunities to study them in detail. From a scientific point of view, the importance of asteroids lies in the fact that they're debris left over from the formation of the Solar System 4.5 billion years ago, which means they can teach us a lot about the distant past. It's also believed that asteroid collisions in the early history of our planet played a role in shaping its biosphere. On a more practical level, asteroids contain many valuable minerals that, due to an asteroid's small size, are generally much closer to the surface than they are on Earth. This makes the mining of NEAs an attractive possibility for the future.

In consideration of the often-underrated importance of asteroids, the United Nations has designated 30 June each year as Asteroid Day. Inaugurated in 2014, this aims to raise public awareness of all aspects of asteroid science, from their role in the formation of the Solar System and their potential as space resources to the importance of defending Earth against future asteroid impacts.

Artist's conception of OSIRIS-REx collecting rock samples from asteroid Bennu

INSIDE AN ASTEROID

Here's how scientists think the interior of an S-type asteroid might look

1 CORE
The densest part of the asteroid is composed of a nickel-iron mixture, similar to an M-type asteroid.

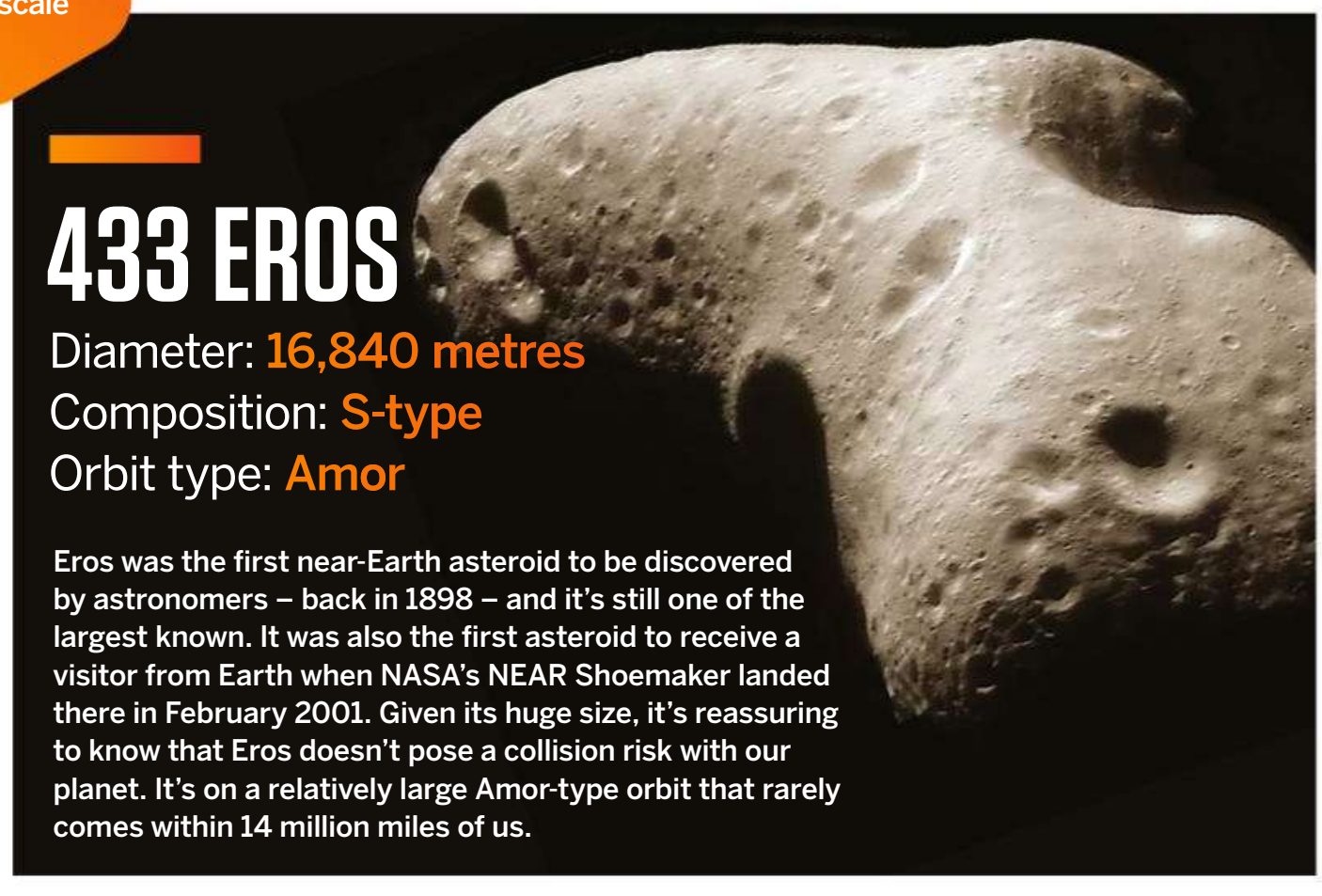
2 INTERMEDIATE ZONE
This contains both cellular nickel-iron and more rock-like silicate minerals.

3 OUTER LAYER
The outer parts of the asteroid consist of silicate material, giving S-type asteroids their bright surface.

4 OTHER CONSTITUENTS
In lesser quantities, S-type asteroids also contain water, rare elements such as platinum and carbonaceous material.

Did you know?

Apophis briefly peaked at 4 on the Torino scale



433 EROS

Diameter: **16,840 metres**
Composition: **S-type**
Orbit type: **Amor**

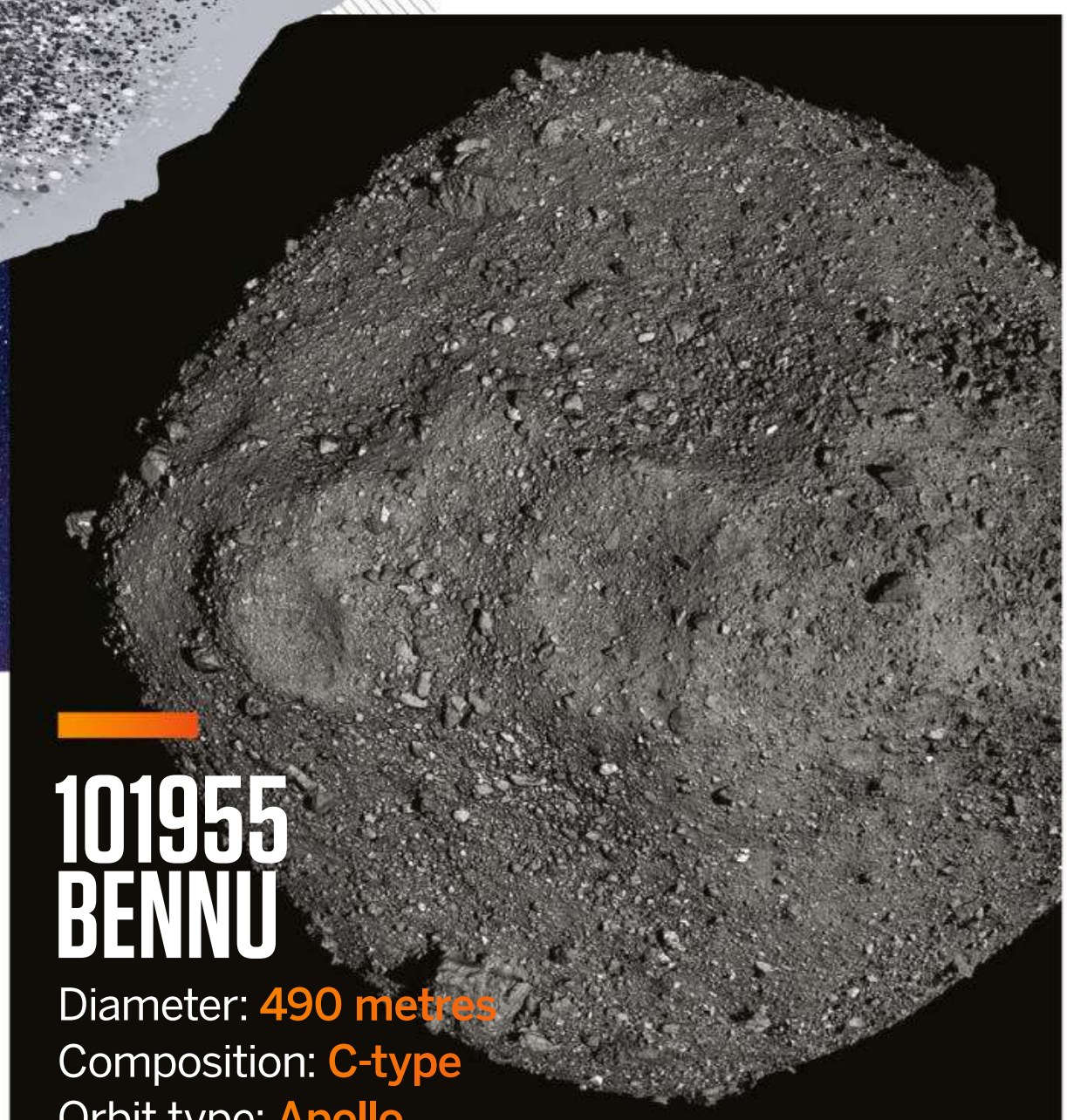
Eros was the first near-Earth asteroid to be discovered by astronomers – back in 1898 – and it's still one of the largest known. It was also the first asteroid to receive a visitor from Earth when NASA's NEAR Shoemaker landed there in February 2001. Given its huge size, it's reassuring to know that Eros doesn't pose a collision risk with our planet. It's on a relatively large Amor-type orbit that rarely comes within 14 million miles of us.

DID YOU KNOW? After delivering its samples to Earth, OSIRIS-REx will go on to study Apophis in 2029

2012 UE34

Diameter: **66 metres**
Composition: **Likely S-type**
Orbit type: **Apollo**

This relatively small asteroid isn't large enough to cause substantial damage even if it did hit Earth, although its orbit brings it close enough to our planet that a collision is a theoretical possibility. Based on current extrapolations of its motion, the closest it will come in the foreseeable future is around 68,000 miles – just over a quarter of the distance to the Moon from Earth – on 8 April 2041.



101955 BENNU

Diameter: **490 metres**
Composition: **C-type**
Orbit type: **Apollo**

Bennu is one of the most closely studied asteroids thanks to NASA's OSIRIS-REx mission, which visited it between 2018 and 2021. During the span of the mission, the spacecraft took numerous close-up images from a distance of a mile or less, as well as collecting rock samples, which are due to arrive back on Earth in September 2023. But Bennu also has another claim to fame – or perhaps notoriety is a better word – as it's the only known asteroid of substantial size that has a measurable chance of hitting Earth at some point in the future. Even so, this won't happen until the last quarter of the 22nd century at the earliest, and even then only with a probability of 1 in 2,700.

THE TORINO SCALE

This measures impact risk on a scale of zero to ten

0

WHITE
This means there's zero chance of an impact or the impactor is so small it will burn up in Earth's atmosphere.

1

GREEN
A routine alert that an object will pass close to Earth with a collision risk that's non-zero, but still so small as to be of no concern.

2 3 4

YELLOW
The chance of collision is around one per cent, meriting attention by astronomers and warnings to the public if less than a decade away.

5 6 7

AMBER
This relates to a close encounter with serious but still uncertain prospects of regional or global devastation, warranting advance contingency planning.

8 9 10

RED
At this point a collision is certain – with consequences that may either be regional or global – and preventive measures become a high priority.

© Alamy / Getty / NASA / Illustartion by Adrian Mann

Artist's impression of how a future asteroid-mining operation might look

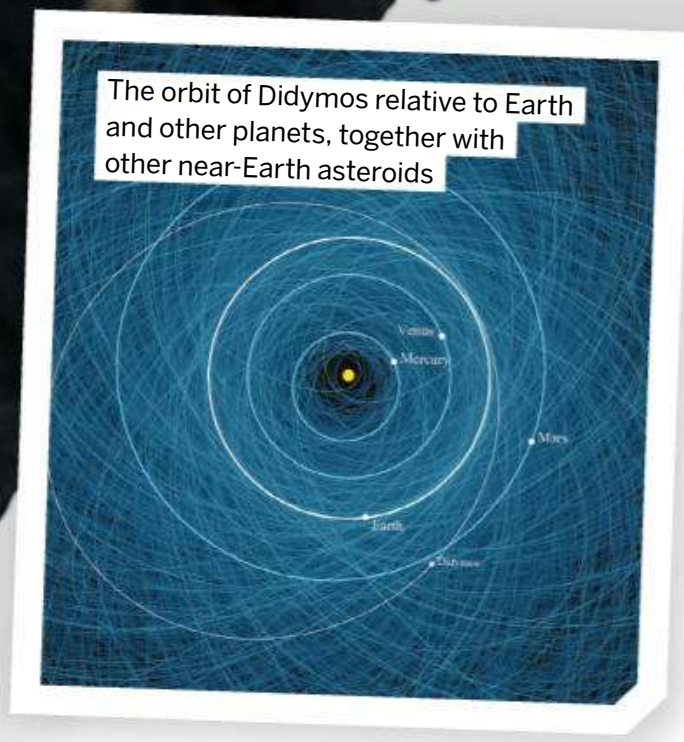
Did you know?

Vesta is the largest known asteroid

367943 DUENDE

Diameter: **30 metres**
Composition: **Likely S-type**
Orbit type: **Aten**

This small asteroid had an extremely close brush with our planet in February 2013, passing within a mere 17,200 miles – little more than four Earth radii – of the surface. As a result of that encounter, Duende's orbit around the Sun changed significantly. Previously it had been on an Apollo-type orbit, but Earth's gravity changed this to a smaller Aten-type orbit. As a result, Duende won't come anywhere near as close to us again for the foreseeable future.



The orbit of Didymos relative to Earth and other planets, together with other near-Earth asteroids

ASTEROID MINING

While there's no risk of collision with the great majority of near-Earth asteroids, they can still be of great interest due to the valuable minerals they contain. For example, heavy elements such as platinum, iridium and palladium – which are extremely rare in Earth's crust – are expected to be far more abundant on or near the surfaces of many asteroids. Such elements aren't just valuable because of their scarcity, but because there's an increasing demand for them in the technology used in phones, laptops and cars. This makes the idea of 'mining' asteroids for these materials extremely attractive. This wouldn't involve the usual kind of mine operated by human miners, and would instead be carried out by specially designed robots that would land on the asteroid, drill down to obtain large quantities of rock samples and then return these raw materials to Earth for processing.

65803 DIDYMOS

Diameter: **765 metres**
Composition: **S-type**
Orbit type: **Apollo**

The most notable feature of this asteroid is that it has a smaller companion, or 'moon', called Dimorphos, which is just 160 metres across. This made the latter an ideal target for NASA's Double Asteroid Redirection Test (DART) in 2022. The idea behind this mission was to test the ability of a spacecraft to alter the path of an asteroid by crashing into it, and the resulting change was much easier to measure if the target was in a tight orbit around another asteroid, rather than a huge orbit around the Sun. Aside from its value as a scientific testbed the Didymos-Dimorphos system doesn't pose any great risk to Earth, rarely coming within several million miles of our planet.

DID YOU KNOW? Amor asteroid 1986 DA contains around 100,000 tonnes of platinum

162173 RYUGU

Diameter: **900 metres**
Composition: **C-type**
Orbit type: **Apollo**

Ryugu is another asteroid that was visited by a spacecraft – Japan's Hayabusa2, which collected samples from the asteroid and returned them to Earth in 2020. Analyses of the samples showed the presence of complex organic molecules, including an RNA nucleobase. Ryugu's next close pass of Earth will be in December 2076, at a range of just under a million miles.

2005 WY55

Diameter: **200 metres**
Composition: **Unknown**
Orbit type: **Apollo**

As with many small asteroids, little is known about this one apart from its orbital path. In the case of 2005 WY55, this periodically brings it close to both Earth and Mars. In the case of our own planet, the next close approach is due on 28 May 2065, when it will pass within 205,000 miles of us – about 90 per cent of the distance to the Moon.

Lewis is a resilience advisor for the civil protection response to asteroid impact events

PROTECTING AGAINST ASTEROIDS

We spoke with Debbie Lewis, a UK specialist on asteroid risk assessment and mitigation

How did you become involved with asteroids, and what's your particular interest in them?
I first became aware of near-Earth objects (NEOs) in 2004 when asteroid Apophis dominated the headlines. I realised the significance of the risk during a visit to the UK National Space Centre while I was studying for a masters in risk, crisis and disaster at the University of Leicester. As a result of this visit, I decided to choose the risk posed from NEOs as the subject for my dissertation.

What sort of measures can we take to protect against asteroid impacts?
Several risk treatment methods have been identified. A research program has been established to find the larger asteroids before they find us, and to conduct characterisation missions to study any potentially hazardous asteroids. Mitigation measures to minimise the effects from an impact event include a kinetic impactor, which was tested and proven to be successful during the DART mission, the gravity tractor and a nuclear device. Civil protection arrangements, such as evacuation and shelter, are required as a contingency in the unlikely event that deflection methods fail.

What are you hoping Asteroid Day will achieve?
In the UK I would like the hazard to be more formally recognised, to be risk assessed and to be included within the National Risk Register and National Security Risk Assessment. In 2021 I contributed to the House of Lords report on preparing for extreme risks, but the Cabinet Office considers that as the impact effects are similar to conventional bomb and blast incidents, no further risk treatment is required. Unfortunately, without the legitimisation of the hazard in the UK, we are unable to start the required preparedness arrangements.

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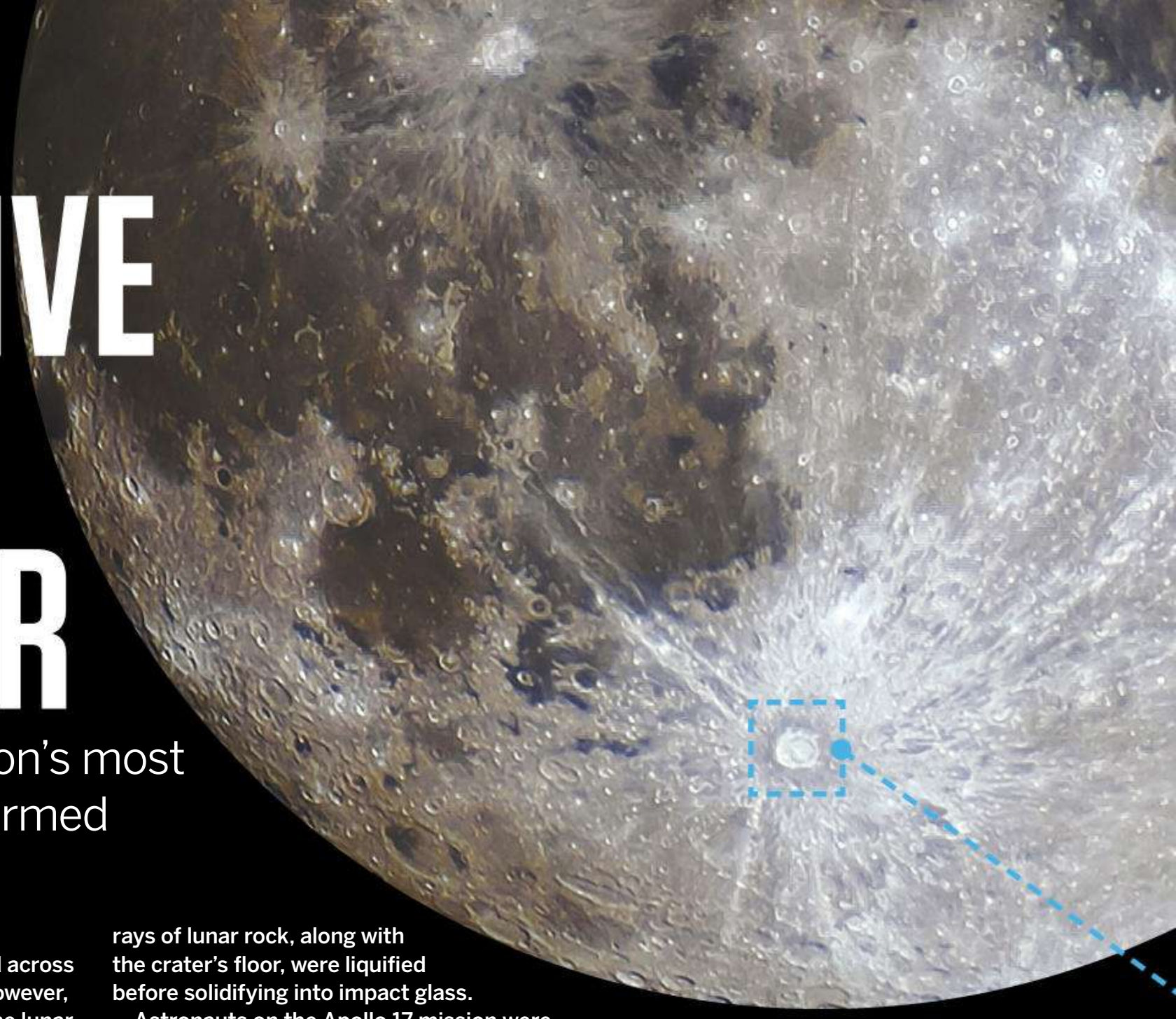
MASSIVE MOON CRATER

How Tycho, our Moon's most prominent crater, formed

WORDS **SCOTT DUTFIELD**



It's estimated that there are millions of craters sprawled across the surface of the Moon. However, one stands out among all the lunar impact sites visible from our vantage point here on Earth. Named after the Danish astronomer, Tycho Brahe, the Tycho crater has long intrigued astronomers. Its high walls, flat floor and central peak make it seem like a city on Earth's natural satellite. Even the Victorian selenographer (someone who charts the Moon) Thomas Gwyn Elger called it "the Metropolitan crater of the Moon".

The walls of the crater span 51 miles wide and plummet around 2.92 miles to its floor. Incredibly, this is small in comparison to the Moon's biggest impact site, the South Pole-Aitken basin, which stretches 1,550 miles in diameter. At its centre is a rocky peak that reaches 1.24 miles into the absent air. The curious peak is characteristic of large craters, the result of rock that was compressed by the massive force of the impact, then immediately rebounded upwards.

Although scientists can't say for sure, it's been suggested that the meteorite that created the crater came from a fragment of the asteroid Baptistina 298. Part of the same asteroid is also believed to have wiped out the dinosaurs and created the Chicxulub crater on Earth around 34 million years after Tycho crater formed.

Following the lunar impact, enormous amounts of rock and broken meteorite, known as ejecta, were thrown from the crater site, creating rays of heated rubble that span around 1,200 miles from the site. Due to the force and heat generated by the impact, the rays of lunar rock, along with the crater's floor, were liquified before solidifying into impact glass.

Astronauts on the Apollo 17 mission were able to snag a rocky sample of the Tycho crater's rays and bring it back to Earth. Upon radiometric analysis, the lunar samples were dated to 108 million years ago. This makes the Tycho crater one of the youngest of all the lunar craters, many of which were formed billions of years ago. Discovering the age of Tycho crater not only helps scientists understand more about the history of this impact site, but helps to unravel the mystery behind the terrain on rocky planets throughout the Solar System.

WHO WAS TYCHO BRAHE?

During the 16th century, Tycho Brahe made some of the most accurate observations possible at the time – before the telescope was invented – about the Solar System. These observations included the order of the Solar System and the positions of more than 777 fixed stars. However, he did not take the same view as fellow astronomer Nicolaus Copernicus, who placed the Sun at the centre of the Solar System. Instead, Brahe believed that the Sun and the Moon orbited Earth, despite also embracing the fact that the other five known planets in the Solar System orbited the Sun. Brahe's observations of the movements of Mars also assisted German astronomer Johannes Kepler's realisation that planets orbit elliptically (a squashed circle) rather than in perfect circles.

A 19th century wood engraving of Tycho Brahe

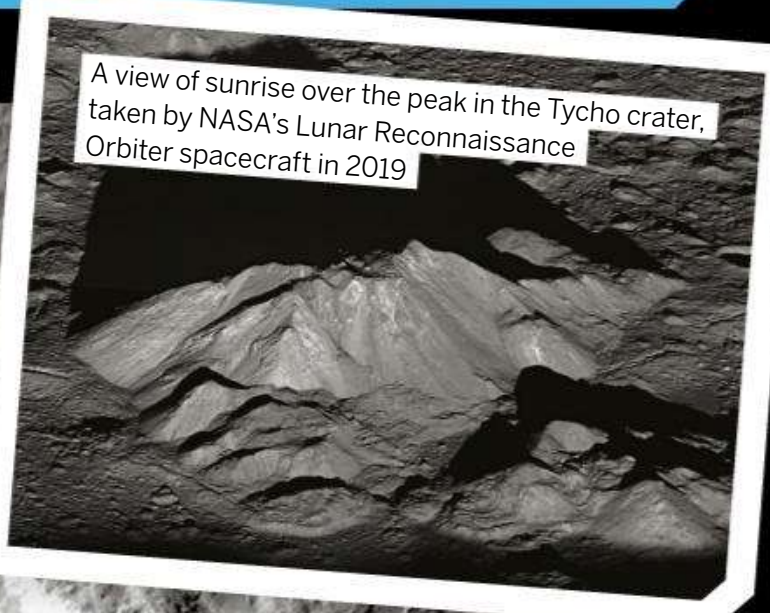
DID YOU KNOW? The unmanned Surveyor 7 spacecraft landed just 18 miles north of Tycho crater's rim in 1968

A mosaic image of the Tycho crater taken by NASA's Lunar Reconnaissance Orbiter

HOW TO SPOT A CRATER

The Tycho crater is found in the southern hemisphere of the Moon, and can be best seen during a full moon. During this phase, the rays around the craters are particularly bright and are easily spotted without the aid of a telescope or binoculars. Under the gaze of a telescope and at a low magnification of 50x, you'll see a closer view of the entire Moon. If you want to explore the finer details of the Tycho Brahe crater, you will need a telescope with a magnification of at least 150x. At this magnification, you'll get a look at details such as the crater's wall, which encompasses a 200,000-square-mile patch on the Moon.

For the best view of the Tycho crater, wait for a full moon



A view of sunrise over the peak in the Tycho crater, taken by NASA's Lunar Reconnaissance Orbiter spacecraft in 2019

Did you know?

Tycho's lunar coordinates are 43.3°S, 11.2°W

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ENVIRONMENT

HOUSEHOLD MINIBEASTS

Meet the creepy critters and pesky pests that find a home in your house

WORDS **SCOTT DUTFIELD**

DID YOU KNOW? Bed bug eggs can survive at temperatures as low as -25 degrees Celsius

A close up of a bed bug extending its sucking mouthparts, called a labium

Did you know?

Bed bugs can feed for ten minutes before they're full

BED BUGS BENEATH THE MATTRESS

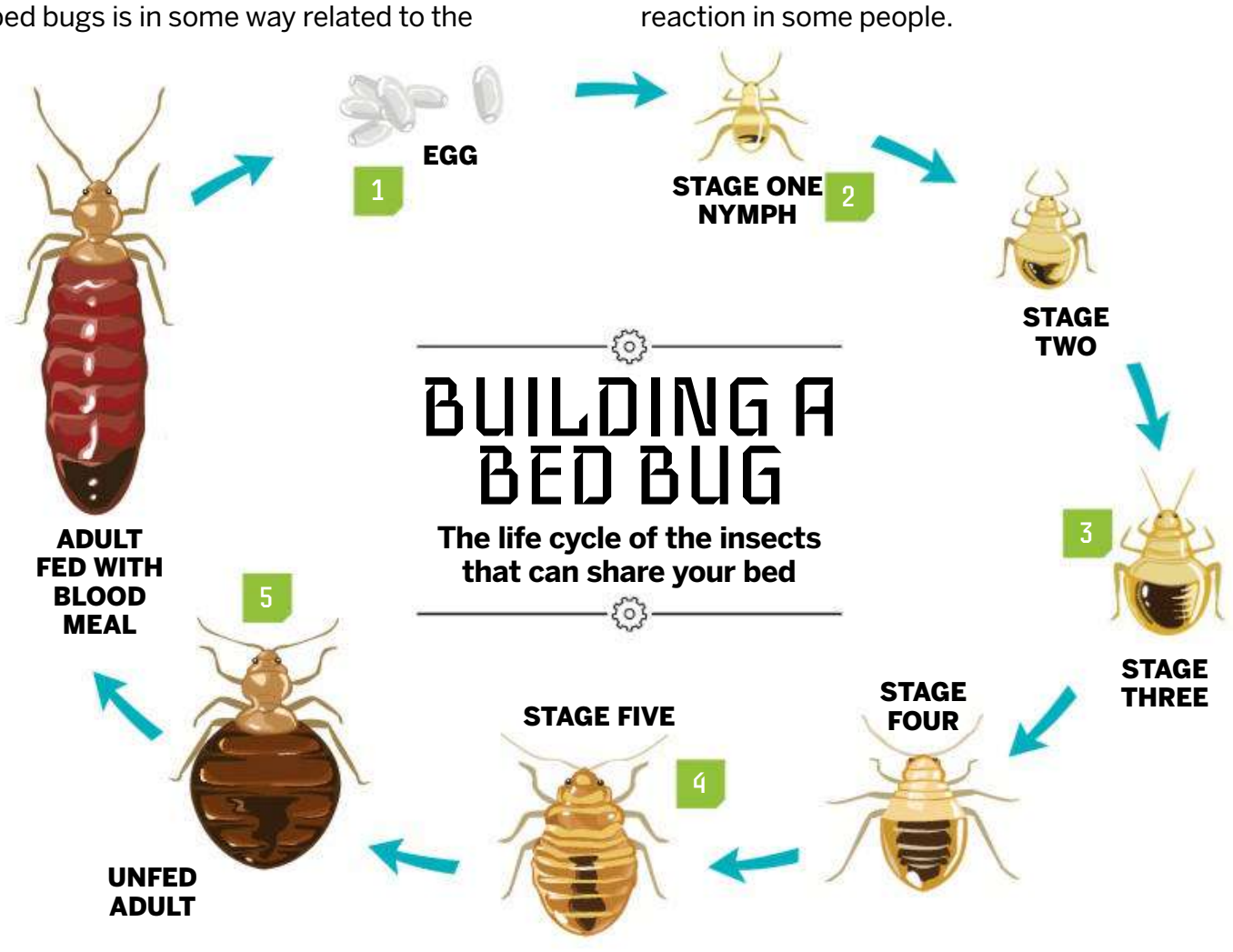
In the US alone, one in five people has had to deal with bed bugs or knows someone that has. Two species of bed bug might be living in your home: *Cimex lectularius* and *Cimex hemipterus*. Usually found in people's beds, these blood-sucking parasites get their name because they prefer to feed on their host while they sleep. Studies have shown that these insects are attracted to the warmth, humidity and most importantly the carbon dioxide levels that surround a sleeping host.

It's a complete myth that the presence of bed bugs is in some way related to the cleanliness of a person's mattress. Bed bugs aren't limited to hiding beneath your bed sheets either – they can be found wherever they can find a food source. Due to their nocturnal nature, they prefer to dwell within the cracks and crevices of walls and floors. One surefire way to know when bed bugs are nearby is by recognising their bites. These parasites feed during the night and leave behind distinctive marks that are raised and red on white skin, or purple on darker skin. Luckily, a bed bug bite isn't known to transmit diseases, but they can cause an allergic reaction in some people.

SOAP-EATING SILVERFISH

Silverfish, sometimes also known as bristletails, are tiny primitive insects that spend their time on the hunt for sugar and starch. The most common silverfish species is *Lepisma saccharina*, but there are around 250 species of silverfish and bristletails around the world. With a preference for damp areas, silverfish are often found in bathrooms munching on the residue of soap. Their noticeable silver appearance comes from the tiny scales that cover their bodies. When threatened, these can pop off – for example, when a predator tries to grab them. Silverfish also have impressive sensory abilities. Despite being deaf and limited to only light and dark vision, their antennae have six different types of receptors that help them indicate the size and shape of their surroundings.

Silverfish are primitive insects with three identifiable bristle-like appendages



BUILDING A BED BUG

The life cycle of the insects that can share your bed

1 LAYING EGGS
Female bed bugs lay around five eggs each day for their entire lives.

2 FIRST BUG
Up to 12 days after the bed bug egg has been laid, it hatches into the first nymph stage.

3 DEVELOPMENTAL STAGES
Bed bug nymphs go through five distinct stages of growth, increasing in size by around 0.5 millimetres at each stage.

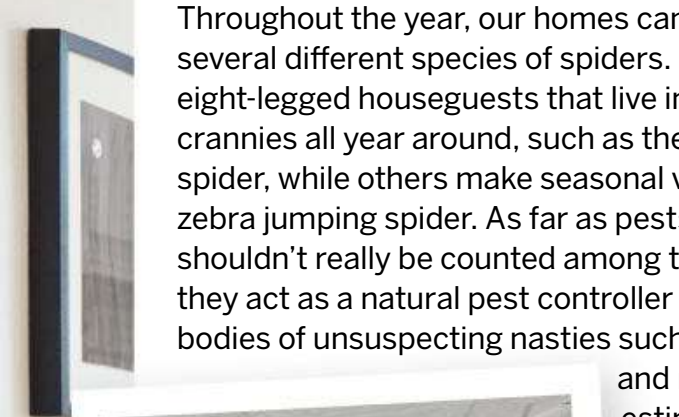
4 MOULTING
Between each stage in their nymphal development, nymphs fill up on blood and shed their tight exoskeleton.

5 ADULTHOOD
After their fifth and final moult, nymphs reach adulthood and will survive for up to 12 months, continually feeding on warm-blooded hosts.

© Getty / Shutterstock

COMMON CRITTERS

Discover the invertebrates that make their way into your home and where you can find them



SPOTTING SPIDERS

Throughout the year, our homes can be shared with several different species of spiders. There are some eight-legged houseguests that live in crooks and crannies all year around, such as the common house spider, while others make seasonal visits, like the zebra jumping spider. As far as pests go, spiders shouldn't really be counted among them. In fact, they act as a natural pest controller and feast on the bodies of unsuspecting nasties such as flies, fleas and roaches. It's estimated that a single spider eats around 2,000 insects every year.

A cellar spider lurking in the corner of the room

A case-bearing clothes moth larvae on the hunt for fresh fabric

FABRIC-MUNCHING FIENDS

Finding food in the finest fabrics, clothes moths are notorious for leaving holes in carpets, clothes and blankets. But it isn't the adult moths that chow down on fibres – it's their larvae. As worm-like larvae, clothes moths feast on a fibrous protein called keratin. Keratin can be found within the wool, silk, leather and feathers of common household items, whereas in the wild, animal carcasses and nesting material provide the keratin these insects crave. It's at this stage in a moth's life that you can identify which of the two known species it belongs to. The larvae of the common clothes moth (*Tineola bisselliella*) create a webbed tube to feed on surrounding fabric, whereas the case-bearing moths (*Tinea pellionella*) build a fabric encasing and carry it around while searching for food.

Did you know?

Cockroaches can run at up to three miles per hour

Cockroaches can eat as much as half their body weight in food per day

COCKROACHES

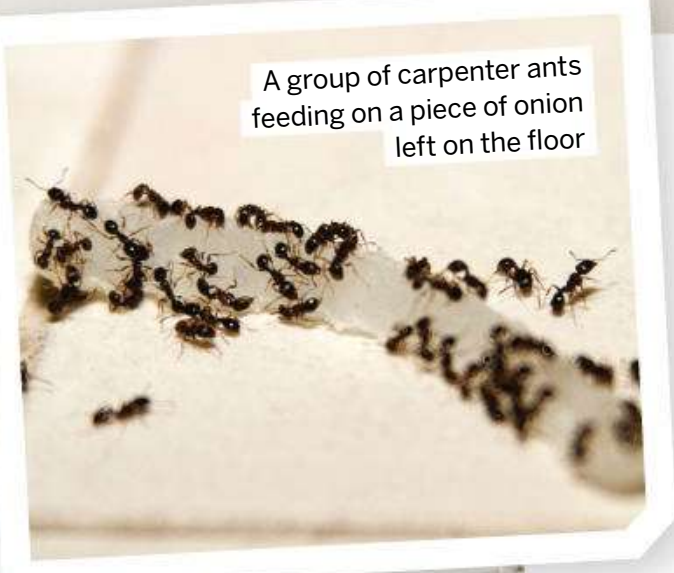
Three different cockroaches can be found in your home: Oriental (*Blattella orientalis*), German (*Blattella germanica*) and brown-banded (*Supella longipalpa*). Each species is attracted to the dark and warm reaches of your home and the humidity created by houseplants. Like many pests, cockroaches scurry through holes in the walls and floors and then spread between homes. A cockroach infestation might be difficult to spot at first because they are most active at night. However, large groups of cockroaches, known as an intrusion, produce an unpleasant almond-like odour that can help us locate them.

DIGGING FOR DUST MITES

Less than a millimetre long, dust mites are microscopic pests that feed on flakes of dead skin and dander from humans and their pets. Although they look like insects, the 13 species of dust mites belong to the same class of animals as spiders: Arachnida. Dust mites are found wherever there's dust. However, mites thrive in warm and humid places with plenty of food – places such as mattresses, carpets and bedding. When inhaled or otherwise ingested, proteins in dust mite poop, as well as in their dead bodies, are responded to as viruses and bacteria by the human immune system and can cause substantial allergic reactions.

An illustration of a dust mite on the hunt for food

DID YOU KNOW? It's estimated that a typical mattress can contain between 100,000 and 10 million dust mites



A group of carpenter ants feeding on a piece of onion left on the floor

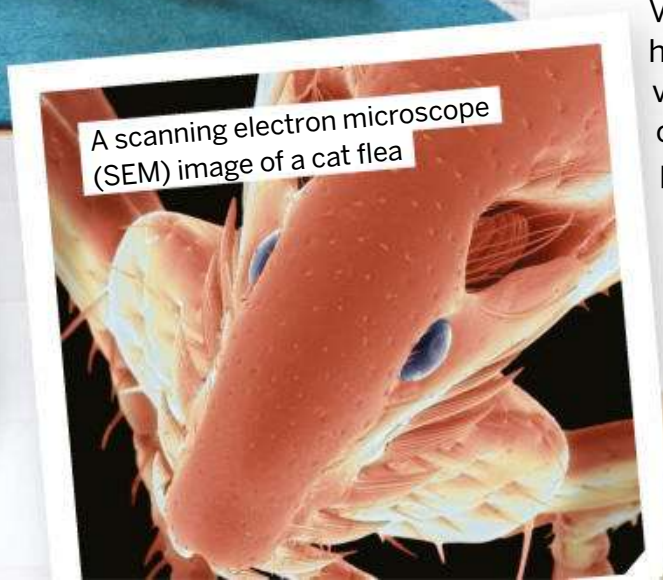
ANT INVADERS

There are likely more than 13,000 species of ants on Earth, with more than 10 quintillion of these minibeasts roaming around. From tropical rainforests to a British back garden, there are few places where ants can't be found, including inside your home. In the UK there are a handful of ant species that journey from the garden and through the front door. The most common ants to pass the threshold are carpenter ants (*Camponotus spp.*), black garden ants (*Lasius niger*) or pavement ants (*Tetramorium caespitum*). As keen cleaners, ants are efficient at removing leftover food from around the house. To signal the location of food to the rest of their colony members, ants drop a trail of pheromonal breadcrumbs leading them to a snack from the nest.

FINDING FLEAS

Often carried home by clothing or by hitchhiking a ride in your pet's fur, fleas are prolific breeders that can spread rapidly. Once they've feasted on their furry hosts, adults mate and females begin to lay eggs in the animal's fur. It takes just ten days for flea larvae to hatch and begin feeding on blood and flea poop, also known as flea dirt. Larvae spend up to 20 days feeding before they spin a silken cocoon to pupate. During this time, they're protected from insecticides until they emerge as adult fleas weeks later.

Various stimuli, such as increased humidity, carbon dioxide and vibrations, can signal the presence of a host to the metamorphosed pupae, prompting it to hatch. After the adult flea has broken through its cocoon, it latches onto the closest host and feeds on their blood for several hours.



A scanning electron microscope (SEM) image of a cat flea

5 SPIDER STOWAWAYS TO LOOK FOR

1 DOMESTIC HOUSE SPIDER (*TEGENARIA DOMESTICA*)

As the name suggests, the domestic house spider has adapted to life inside our homes all year around. They typically spend their time in their webs until males venture around the house in search of a mate. These spiders are the largest species to be found inside and can grow up to a leg span of 12 centimetres.

2 FALSE WIDOWS

While many spiders that might find their way into our homes are harmless, there's one venomous group to watch out for: false widow spiders. There are six species of false widow spiders in the UK; the three most common are the rabbit hutch spider (*Steatoda bipunctata*), the cupboard spider (*Steatoda grossa*) and the noble false widow (*Steatoda nobilis*).

3 MISSING SECTOR ORB WEAVER (*ZYGIELLA X-NOTATA*)

These orb-weaving spiders aren't ever far away from human homes. All year round this species build their circular homes in the window frames, gutters and plants around human dwellings. This species is often mixed up with the false widow spider but is not harmful to humans.

4 ZEBRA JUMPING SPIDER (*SALTICUS SCENICUS*)

One of the 5,000 species of jumping spiders found around the world, zebra spiders can be found leaping around the exterior walls of a home and often through open windows and doors. However, you'll be hard-pressed to spot them as they are only six to seven millimetres long and can jump 14 times their body length.

5 LACE WEAVER SPIDER (*AMAUROBIUS SIMILIS*)

Often found hanging from the corners of back door frames, garden walls and fences, the lace weaver spider spins a silky web that resembles lace. There are three related species of lace weaver spiders in the UK: the lace weaver, window spider (*Amaurobius fenestralis*) and black lace weaver (*Amaurobius ferox*).

© Getty / Alamy

A termite colony building their nest from their woody waste products

WOOD-HUNGRY TERMITES

Around the world there are about 2,800 species of termites, which are generally split into two categories: subterranean termites and dry-wood termites. Subterranean termites burrow underground to benefit from the moisture in their environment, whereas dry-wood termites are more adapted to life above ground. Both share one fundamental similarity: an appetite for wood, or rather a chain of glucose molecules found in wood called cellulose. To digest wood and extract the cellulose, termites have a group of different bacteria and single-celled eukaryotes called protozoa in their digestive system that transform the wood, along with nitrogen taken from the air, into a protein, releasing energy for the termites. Termites aren't born with this internal biological community and are fed a small sample by their parents to get their digestive biome blooming.

Around 90 to 98 per cent of all termites in a colony are worker termites, which are sightless and spend their time creating the countless tunnels that make up the colony's nest. The rest of the termite family is made up of soldiers responsible for defence and reproduction. They spend their time mating with termite queens, of which there are several. A termite queen ensures the persistence of these pests by continually supplying new troops and can lay around 30,000 eggs per day.

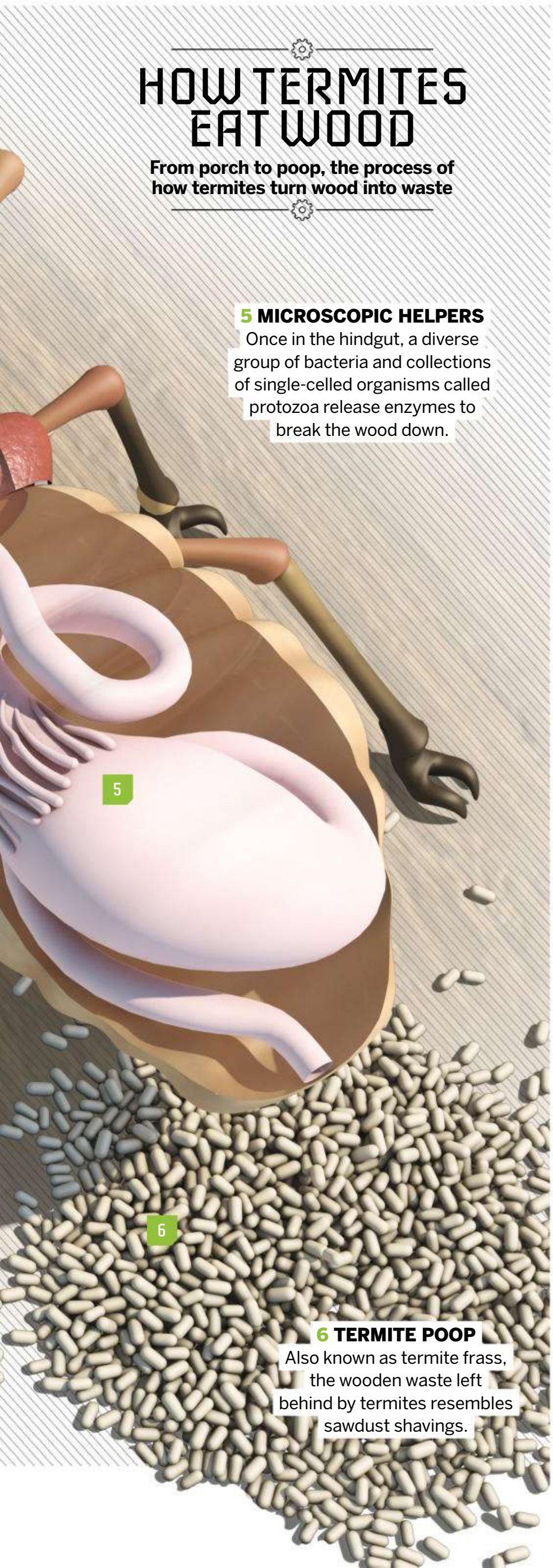
1 FINDING FOOD
While digging underground, termites might stumble across a wooden food source. Like ants, they use a system of pheromones to call other termites to feed.

2 MIGHTY MANDIBLES
Termites are equipped with strong and robust pincer-like mandibles to chip away at wood.

3 FAST JOB
It doesn't take termites long to chow down on wood. They can consume up to 450 grams in 24 hours.

4 INTO THE DIGESTIVE TRACT
Wood passes through the termite's digestive system, which includes an oesophagus, crop and midgut, before reaching the hindgut.

DID YOU KNOW? In her 20-year life span, a single termite queen will lay around 219 million eggs

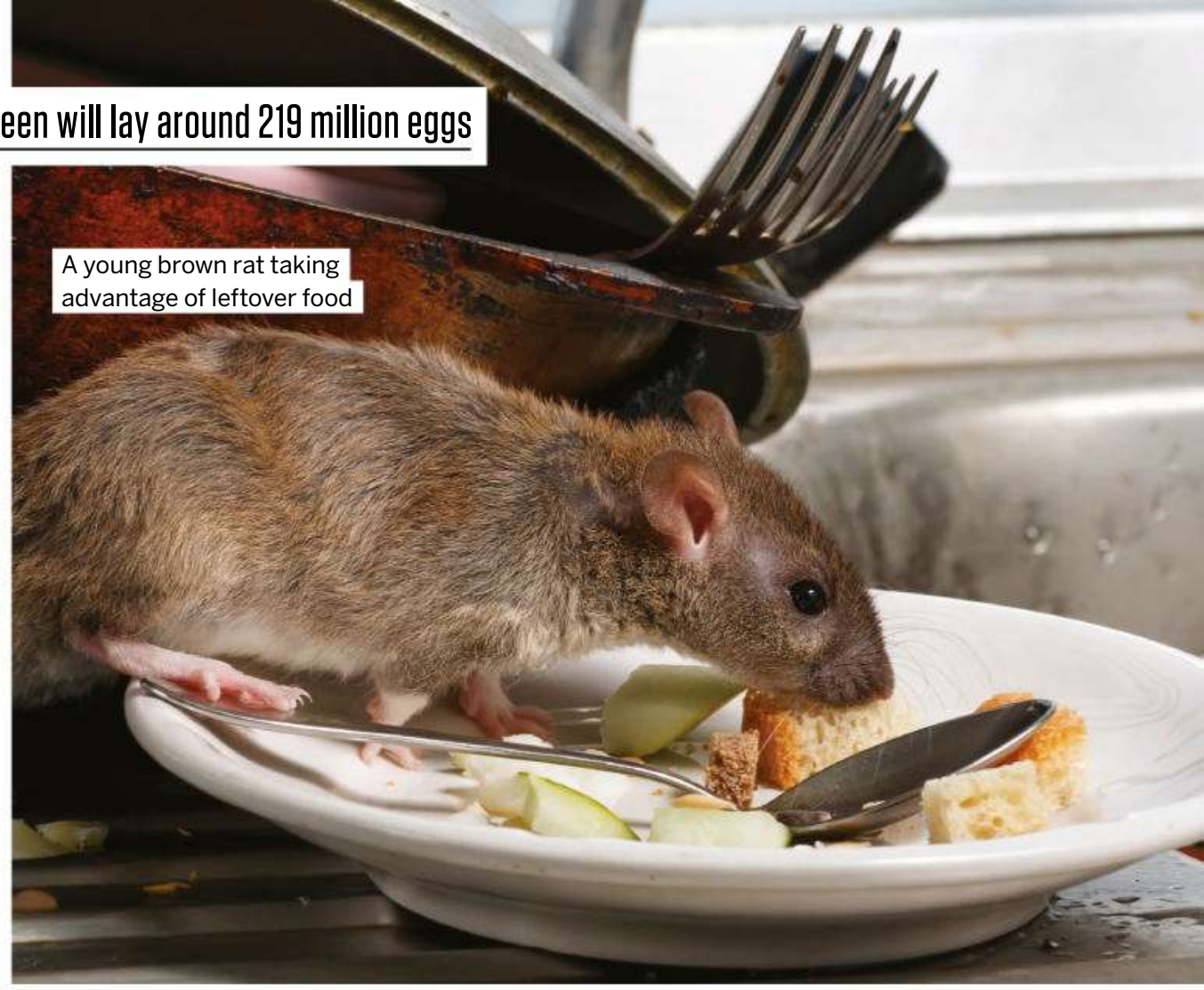


HOW TERMITES EAT WOOD

From porch to poop, the process of how termites turn wood into waste

5 MICROSCOPIC HELPERS
Once in the hindgut, a diverse group of bacteria and collections of single-celled organisms called protozoa release enzymes to break the wood down.

6 TERMITE POOP
Also known as termite frass, the wooden waste left behind by termites resembles sawdust shavings.



A young brown rat taking advantage of leftover food

RODENT ROOMMATES

Within the UK, there are two species of rats that can be found scurrying beneath the floorboards: the brown rat (*Rattus norvegicus*), also known as the common rat, and the black rat (*Rattus rattus*). Black rats are rare, and sightings are often limited to shipping ports. Brown rats, on the other hand, are found almost everywhere in the UK and find shelter in places with plenty of food and water. In homes these places include roof space and under floorboards, as well as within sewer systems.

Along with stealing your food, rats carry with them a whole host of potential diseases that pose a risk to human health. Like many mammals, rats mark their territory using their urine. It's from their urine that diseases such as listeriosis, leptospirosis and hantavirus can be contracted.

Famously during the 14th century, across Europe black rats were condemned as spreaders of the Black Death, or bubonic plague. It was believed that the rodents of the Late Middle Ages carried a bacteria called *Yersinia pestis* that caused the plague. When fleas feasted on bacteria-laden rat blood, they inadvertently transmitted it to human hosts through their bite. However, while the rats do indeed carry the deadly bacteria, recent studies suggest that it came from gerbils brought over to Europe through the Silk Road trade route from Asia.

SIGNS OF A RAT INFESTATION

1 DROPPINGS
Rats produce up to 40 droppings per night. They look like slim pellets around one centimetre long. Fresh ones are dark brown and will become lighter as time passes.

2 RUBBING MARKS
The grease and dirt found on the fur of rats rubs off onto the skirting boards and walls in the rooms where rats have been. In low light, rats use skirting boards to navigate around the house.

3 SCRATCHING SOUNDS
The most immediate sign of rats is the sound they make when scurrying through attics and under floorboards. Brown rats also make a notable grinding sound with their teeth.

4 RAT NESTS
These rodents tend to shred materials such as cardboard and insulation and construct soft nests in the crooks and crevices around your house.

5 RODENT HOLES
As keen burrowers, rats dig holes around a property to store food, take shelter and build extensive burrows. There may also be footprints from the rats entering and exiting these holes.

© Getty / Illustration by Adrian Mann

WHY GLITTER IS SO BAD FOR THE PLANET

How this microplastic wreaks havoc on our bodies and the environment

WORDS **SCOTT DUTFIELD**

Since the early 20th century, glitter has sparkled its way into nearly every corner of the world.

The concept of glitter has been around since around 40,000 BCE, when ancient civilisations around the world applied shiny minerals called mica, still used today in cosmic highlighters, to bring some sparkle to their faces. However, the pesky plastic variety we've come to know and love, or in many cases hate, was invented by American machinist Henry Ruschmann in 1934. Ruschmann invented a mechanical way to grind down plastic in a way that's reminiscent of paper shredding and wood chipping to make shiny glitter in large quantities.

The sparkly nature of glitter comes from a process called metalisation, which applies an aluminium coating to either side of a piece of plastic film called polyethylene terephthalate (PET). To make the aluminium adhere to the film, it is evaporated in a vacuum chamber and sprayed onto a plastic film. For metallic glitter, a coloured or clear coating is applied over the aluminium layer, while holographic and iridescent glitters use an additional film, which reflects certain wavelengths in the light spectrum. Sheets of glitter plastic are then cut into a variety of shapes and bottled.

Along with being visually attractive, glitter also seems to be physically attracted to every surface it comes in contact with. There are several explanations for glitter's ability to cling to anything, including static electric attraction and the viscosity of the air – a phenomenon that, on a small scale, acts as a fluid holding glitter in place. Similarly, a phenomenon called Van der Waals forces, which describes attractive and repulsive forces between molecules, could play a part in its stickiness.

From cosmetic make-up and craft projects to industrial paints, glitter is used all around the world. One of the world's biggest suppliers of glitter, called Glitterex, however, is tight-lipped when it comes to the biggest buyer of glitter. Many online conspiracies point the finger at the military for its potential use in explosives, while others speculate that the production of money might be the true hoarder of glitter. The truth, however, remains locked behind the doors of the world's glitter factories.

As a form of plastic, glitter has a dark side. Glitter pieces are small enough – below five millimetres in diameter and even thinner – to be classed as microplastic. Microplastics are an environmental hazard, particularly when they reach the world's oceans. Some marine species often mistake glitter for fish eggs and ingest them, leading to malnutrition, and can also affect reproduction for some marine species. There are also concerns about the long-term effects that microplastics will have on human health through aquatic food chains. Glitter is also largely non-biodegradable, and can remain in the environment for around 1,000 years.

Glitter is cut into a variety of shapes, most commonly tiny hexagons

A coloured coating gives glitter its hue

Did you know?

There are around 8 million tonnes of glitter in the world's oceans

DID YOU KNOW? In 2017, the UK government banned microplastics, including glitter, from use in toiletry products

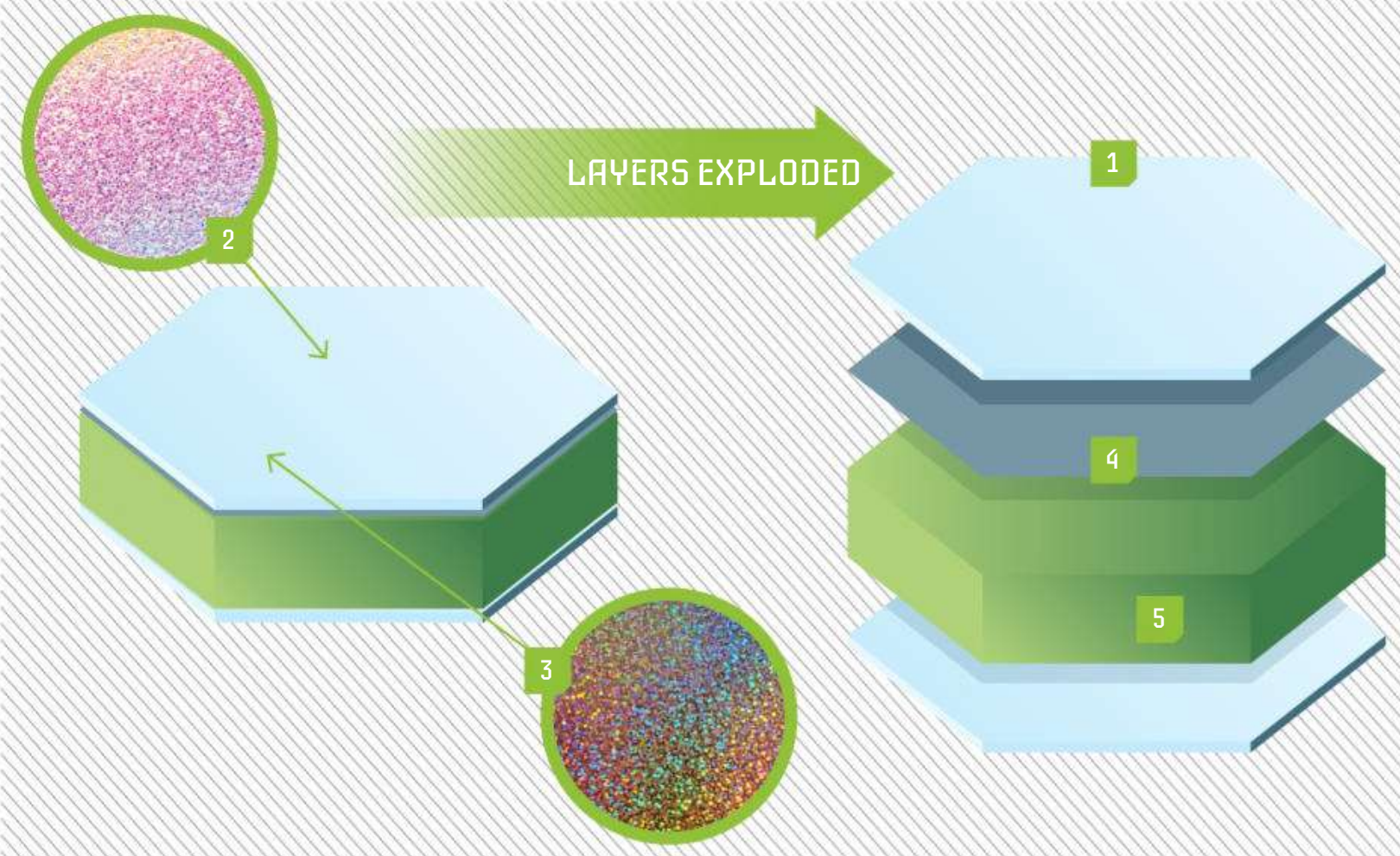
SWAPPING PLASTICS FOR PLANTS

Bio-glitter can provide all the glint and glamour of glitter without wreaking havoc on the environment. In place of a plastic film, bio-glitter uses plant-based materials called cellulose that is extracted from trees, typically fast-growing eucalyptus. Through a process called self-assembly, cellulose molecules are heated in water, and as the water evaporates it forces the cellulose molecules to align and form a plastic-like polymer and the basis for bio-glitter. Unlike plastic glitter, bio-glitter is mostly biodegradable in the environment. Under typically degradable conditions, which include the presence of heat, water and microorganisms, it can decompose into carbon dioxide, water and biomass, which is used in the growth of new plant life. However, they are not all 100 per cent biodegradable, as a small percentage of trace plastics remain in many bio-glitters.

Cellulose for bio-glitter is extracted from sustainable-source eucalyptus trees

BREAKING APART BIO-GLITTER

The shiny layers that make up a single fleck of bio-glitter



1 COATING
A plastic coating is applied to surface a glitter fleck, which is either clear to reveal the metallic aluminium below or coloured to change its shade.

2 IRIDESCENCE
For glitters that appear iridescent, a plastic film of microlayers is used inside instead of an aluminium layer to refract light to such a degree that they appear iridescent.

3 HOLOGRAPHIC
A pattern of microscopic grooves are embossed on the plastic coating, which cause light to diffract into a full spectrum of colour.

4 ALUMINIUM LAYER
The reflective layer of bio glitter consists of a layer of aluminium that is thousands of times thinner than a human hair.

5 FILM CORE
The majority of the bio-glitter is made up of regenerated cellulose made into a film, which lets light pass through and reflect off the aluminium layer.

5 WEIRD USES FOR GLITTER

1 POOP TRACKER
Researchers at the Lindner Center for Conservation and Research of Endangered Wildlife at the Cincinnati Zoo incorporated a small amount of glitter in the food of female polar bears as a biomarker to distinguish their poop from males' for studies of reproductive hormones.

2 CRIME SOLVER
Due to its persistence in the environment, glitter has been used in forensic science to match a suspect with a victim. As a form of contact trace evidence, glitter is easily transferred from one person to another.

3 FISH LURE
Humans aren't alone in their love of glitter. Fish are attracted to shiny objects, so some fishing lures incorporate glitter in their design to catch a bite.

4 MILITARY WEAPON
Both the US and UK air forces experimented with using glitter-like materials as decoy called 'chaff' during World War II. While in flight, military pilots deployed flecks of aluminium-coated paper to confuse enemy radars.

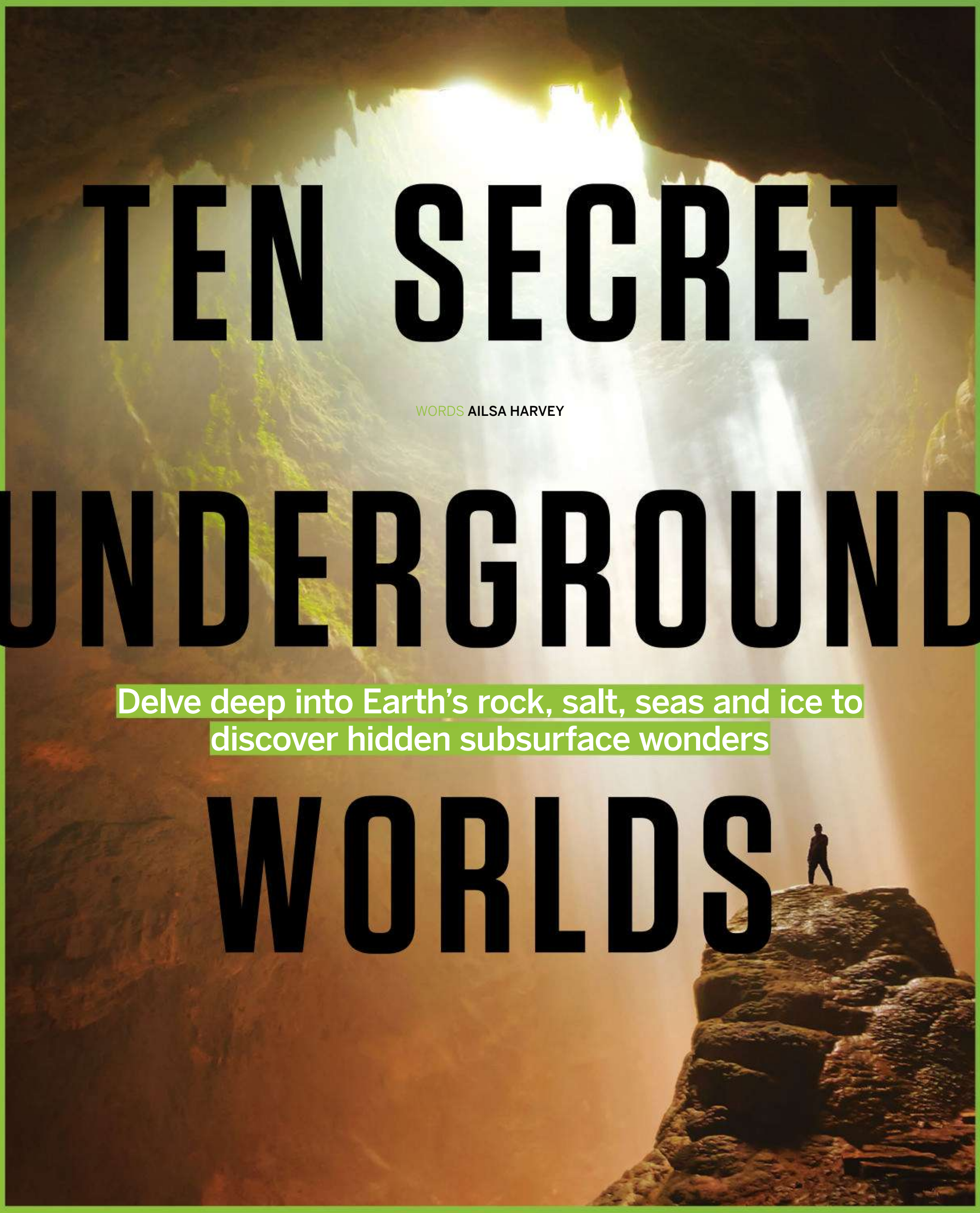
5 COFFIN COATING
Why not add some extra pizazz to your final resting place by covering a coffin in glitter? Some coffin creators in the UK offer their clients bespoke glitter coffins in a range of colours for a flamboyant funeral.

© Getty / Alamy

TEN SECRET UNDERGROUND WORLDS

WORDS **AILSA HARVEY**

Delve deep into Earth's rock, salt, seas and ice to discover hidden subsurface wonders



DID YOU KNOW? The humidity in Naica's crystal cave can reach 90 per cent

1 CAVE OF GIANT CRYSTALS

NAICA MINE, MEXICO

Naica's crystal cave was first discovered by miners in 1910 and is home to giant selenite crystals. These are made of the mineral gypsum, with the largest crystal measuring 12 metres in length and four metres thick. Heat from the magma below aided in the formation of these giant gems, but it also makes a visit to this underground wonder extremely uncomfortable. Temperatures of 58 degrees Celsius have been recorded in this 120-metre-deep cave, preventing access to tourists. When scientists investigate the towering translucent structures, they need to wear special cooling suits to survive in this jagged crystalline world. A maximum time of 45 minutes can be spent in the cave even with these suits. Overstaying in Naica's crystal cave increases the chances of scientists' lungs filling with liquid as it condenses from the air inside the body.

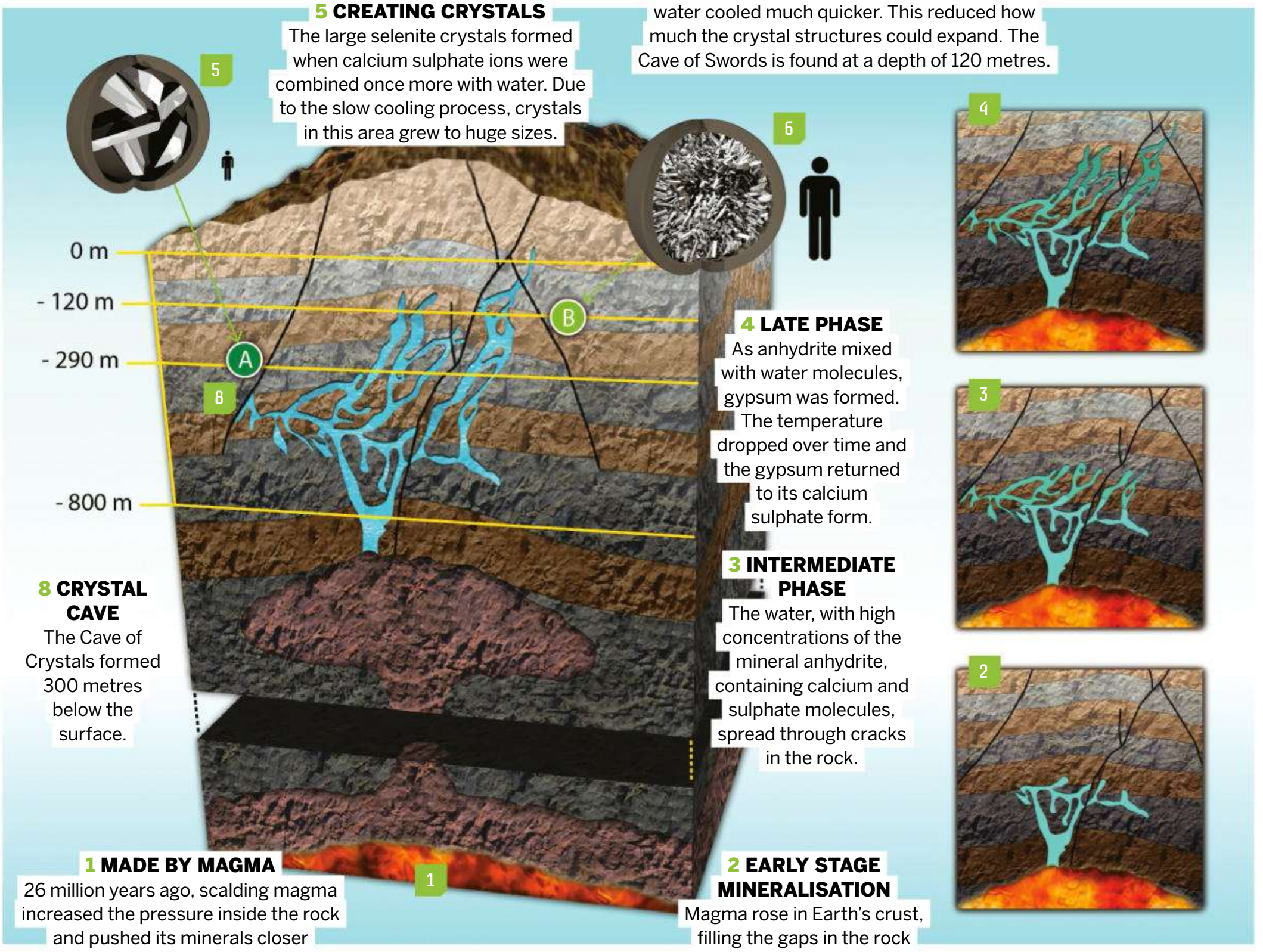
Did you know?

80 cavers worked to map Malham salt cave

The largest crystal discovered in Naica weighed 55 tonnes

HOW THEY FORMED

Somewhere between Earth's molten mantle and solid surface, magma made Naica's massive crystals



5 CREATING CRYSTALS
The large selenite crystals formed when calcium sulphate ions were combined once more with water. Due to the slow cooling process, crystals in this area grew to huge sizes.

6 GETTING SMALLER
In this area, closer to the surface, the mineral-rich water cooled much quicker. This reduced how much the crystal structures could expand. The Cave of Swords is found at a depth of 120 metres.

4 LATE PHASE
As anhydrite mixed with water molecules, gypsum was formed. The temperature dropped over time and the gypsum returned to its calcium sulphate form.

3 INTERMEDIATE PHASE
The water, with high concentrations of the mineral anhydrite, containing calcium and sulphate molecules, spread through cracks in the rock.

8 CRYSTAL CAVE
The Cave of Crystals formed 300 metres below the surface.

1 MADE BY MAGMA
26 million years ago, scalding magma increased the pressure inside the rock and pushed its minerals closer towards Earth's surface.

2 EARLY STAGE MINERALISATION
Magma rose in Earth's crust, filling the gaps in the rock above with mineral-rich water.

© Alamy / Science Photo Library / Wikimedia Common/ Albert Vila

2 LIFE INSIDE MAMMOTH CAVE

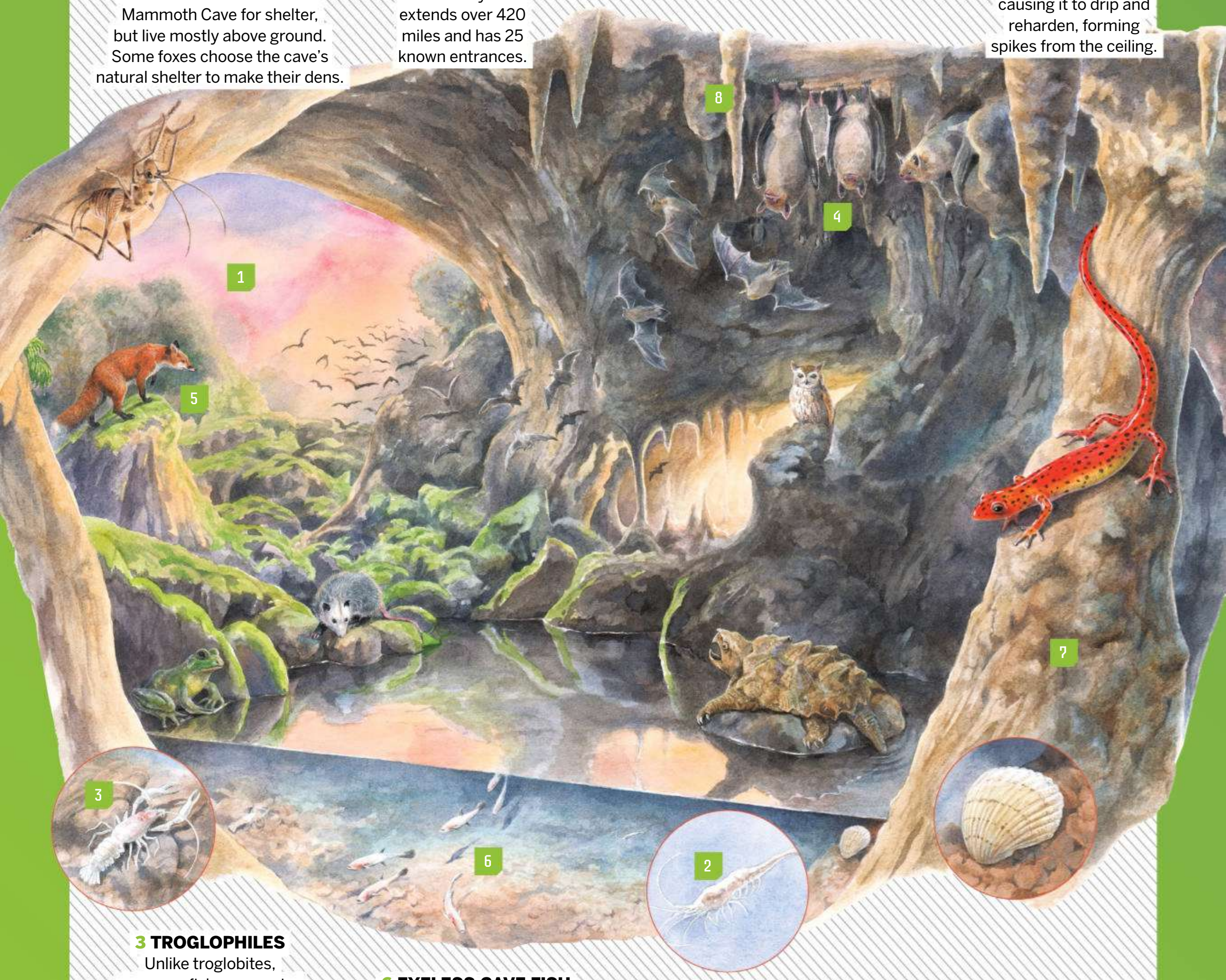
Over 200 species live in the world's longest cave system, in Kentucky, USA

5 SURFACE ANIMALS
These animals venture into Mammoth Cave for shelter, but live mostly above ground. Some foxes choose the cave's natural shelter to make their dens.

1 ENTRANCE
The cave system extends over 420 miles and has 25 known entrances.

4 TROGLOXENES
'Cave guest' species spend much of their time sheltering in caves. Bats of Mammoth Cave sleep inside, but leave to find food. Permanent cave dwellers feed on their leftovers.

8 STALACTITE FORMATION
Many stalactites decorate the wetter areas of the cave. These form when water dissolves the limestone, causing it to drip and reharden, forming spikes from the ceiling.



3 TROGLOPHILES
Unlike troglobites, cave crayfish can survive outside the cave but prefer dim environments. They have no eyes and are translucent, relying on their sensitive feelers to navigate between the cave's many pools.

6 EYELESS CAVE FISH
Many of the fish in this cave have evolved to have no eyes. The loss of these organs helps their bodies save energy that's instead used to find food in the extreme habitat.

2 TROGLOBITES
The Kentucky cave shrimp is a troglobite, meaning it can only live underground. This endangered creature lives in the dark streams of Mammoth Cave.

7 ROCK FORMATION
The limestone of Mammoth Cave formed 330 million years ago.

DID YOU KNOW? Scientists estimate that a further 596 miles of Mammoth Cave is unexplored

3 COLOSSAL CAVE

SON DOONG CAVE, VIETNAM

Son Doong cave was officially measured in 2009

Measuring 38.5 million cubic metres, Son Doong cave in the Quang Binh province of Vietnam is regarded as the largest cave in the world by volume. It's five times larger than the previous title holder – Deer Cave in Malaysia. Inside this cavity are unique underground ecosystems and limestone features carved by nature. These include awe-inspiring stalagmites up to 80 metres tall protruding from the ground and calcite carbonate pearls that have dripped from the ceilings and hardened into smooth, rocky spheres on the cave floor. The chamber of the world's largest stalagmite is so huge that a Boeing 747 aeroplane could fly through its 5.6-mile-long passageway with ease.

Throughout the cave are numerous spacious underground chambers, giving the entire cave an average height of 200 metres and width of 150 metres. Even where Son Doong shows weakness, beauty has followed. There are two passageways in the giant cave that have a gap in the ceiling where the rock has fallen through. These events have created two large natural skylights, further highlighting the cave's features and providing a majestic sight as light pours into the otherworldly locales below. Through these gaps, the sunlight sustains plant life. Trees up to 40 metres tall grow underground, providing a unique ecosystem and contrasting scenes of forest and cave.

4 GLOWING WORLD OF WORMS

WAITOMO CAVES, NEW ZEALAND

Fully experiencing the natural beauty of most caves requires some artificial light to overcome the complete darkness underground. However, the view in Waitomo Caves on the North Island of New Zealand is best appreciated with all torches turned off. As your eyes adjust to the subtle natural lighting of this cave, thousands of glowworms display their bioluminescent light. At the tails of these maggot-like animals, a molecule called luciferin is released. As this reacts with the oxygen in the cave, the glowworms' tails light up with a blue-green hue. The flickering patterns dispersed throughout the cave could be compared to the stars in a clear night sky, but it's other insects, not humans, that these creatures aim to captivate. Hanging below each glowworm is a long, sticky thread that they release as a trap. When insects fly towards their bioluminescent display, the underground glowers pull this string back towards them and feast on the trapped prey.

Did you know?

Glowworms are in the larval stage of their life cycle

Tour guides will turn off all the lights to show off the glowworms' natural display

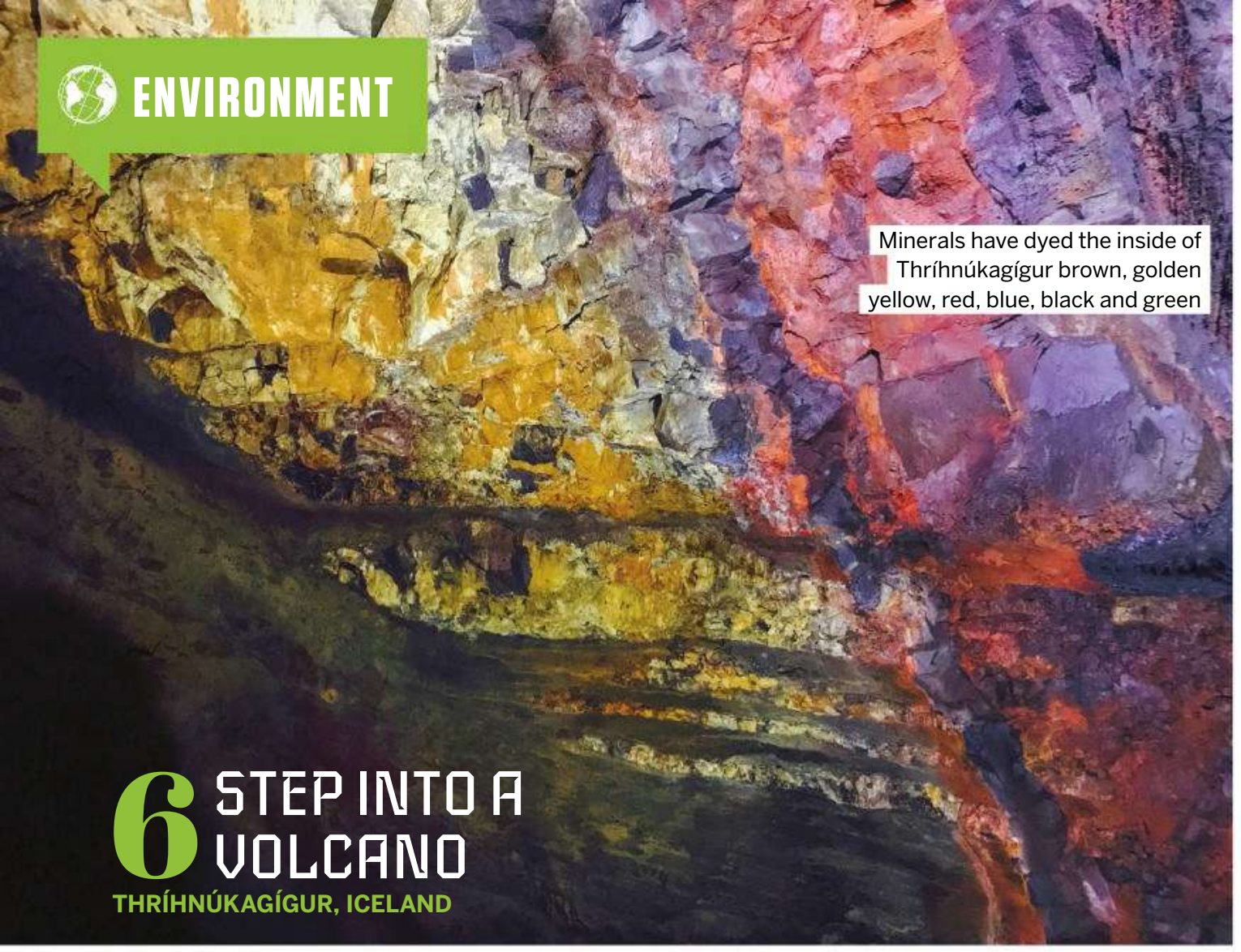
5 EXPANSIVE SALT CAVE

MALHAM SALT CAVE, ISRAEL

Inside Mount Sodom, near the Dead Sea, is a meandering network of tunnels decorated with salt crystal daggers. These tunnels cover over 6.2 miles, making this salt cave the longest in the world. Mount Sodom has a composition of around 80 per cent salt. As surface water seeped through the mountain 7,000 years ago, the salt was dissolved to form passageways. Within this salty maze there are around 100 chambers branching from the cave. Despite forming in one of the world's driest locations, with only around 50 millimetres of rainfall annually, this cave has taken shape relatively quickly. Limestone caves take much longer than a few thousand years to form, but the high solubility of the salt has allowed the rain that seeps into the mountain to carve this cave rapidly. Malham salt cave continues to grow today, with many of its passages yet to be explored.

Mount Sodom is mostly salt, creating long salt stalactites in the salt cave

© Alamy / Getty / Shutterstock



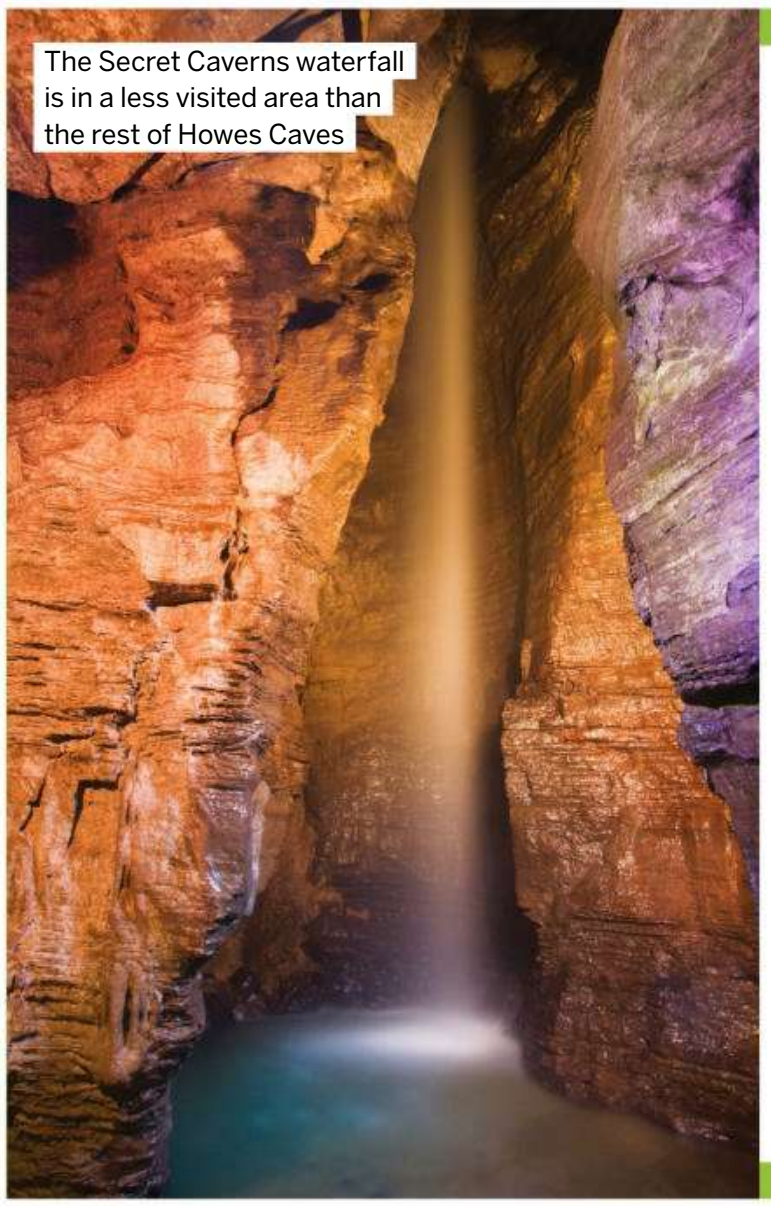
Minerals have dyed the inside of Thríhnúkagígur brown, golden yellow, red, blue, black and green

6 STEP INTO A VOLCANO

THRÍHNÚKAGÍGUR, ICELAND

Spanning the boundary of the Eurasian and North American tectonic plates, active volcanoes are abundant in Iceland. But only one of the country's volcanoes can be explored in depth from the inside: Thríhnúkagígur. With a funnel-shaped opening, this dormant volcano can be accessed as part of a small tour group. The volcano hasn't erupted for 4,000 years, but the fiery and vibrant colourings of its magma chamber are mesmerising traces of the minerals spewed from this spot long ago. There's no other volcano in the world that you can step inside the chamber of, and the rainbow rocks serve as a reminder of the extreme natural forces these passages had to endure when connecting the planet's surface to deep within the Earth.

The volcano is accessible by small groups as part of a guided tour, where visitors can take in the scarred and scalded rock that was once exposed to a high-pressure explosion of toxic gas and magma.



The Secret Caverns waterfall is in a less visited area than the rest of Howes Caves

7 NEW YORK'S UNDERGROUND WATERFALL

HOWES CAVE, NEW YORK

Inside the Secret Caverns chamber of Howes Caves in New York, water cascades underground, falling over 30 metres from the top of the cave. This waterfall produces a thundering echo into the cave and can only be witnessed by travelling 25 metres below ground level.

Underground waterfalls like this one are formed when high volumes of water and the sediment it carries erode the soft rock of the cave ceiling. As this soft rock disappears, a step is formed, over which the water falls. When this occurs over hollow ground, the soft rock breaks away to connect the waterfall to the inside of the cave. In the Secret Caverns the falling water has produced a small pool below the level of the rest of the cave floor.

8 DEEP INTO THE BLUE

GREAT BLUE HOLE, BELIZE

What lies at the bottom of this giant ominous dark patch off the coast of Belize? At 300 metres in diameter, this is the world's largest ocean sinkhole, sinking down to 125 metres below the surface. A blue hole is an ocean depression enclosed by land, and the Great Blue Hole is surrounded by limestone walls. This rock extends below the surface, enclosing the ocean water inside to form an intricate underwater cave.

This blue hole formed in the last ice age as a limestone cave above the water level. However, when sea levels began to rise and flooded the cave, it was converted into a scuba diving wonderland. Those brave enough to venture down into its dark waters will be greeted by an array of sea life communities that call this sheltered undersea world their home. Some of these animals include sponges, molluscs, turtles and sharks.

The Great Blue Hole is around 150,000 years old

DID YOU KNOW? Thríhnúkagígur's magma chamber was discovered in 1974 and was opened to the public in 2012

9 ANTARCTICA'S SUBGLACIAL LAKE

The largest known subglacial lake in the world has been protected by a thick icy layer for millennia

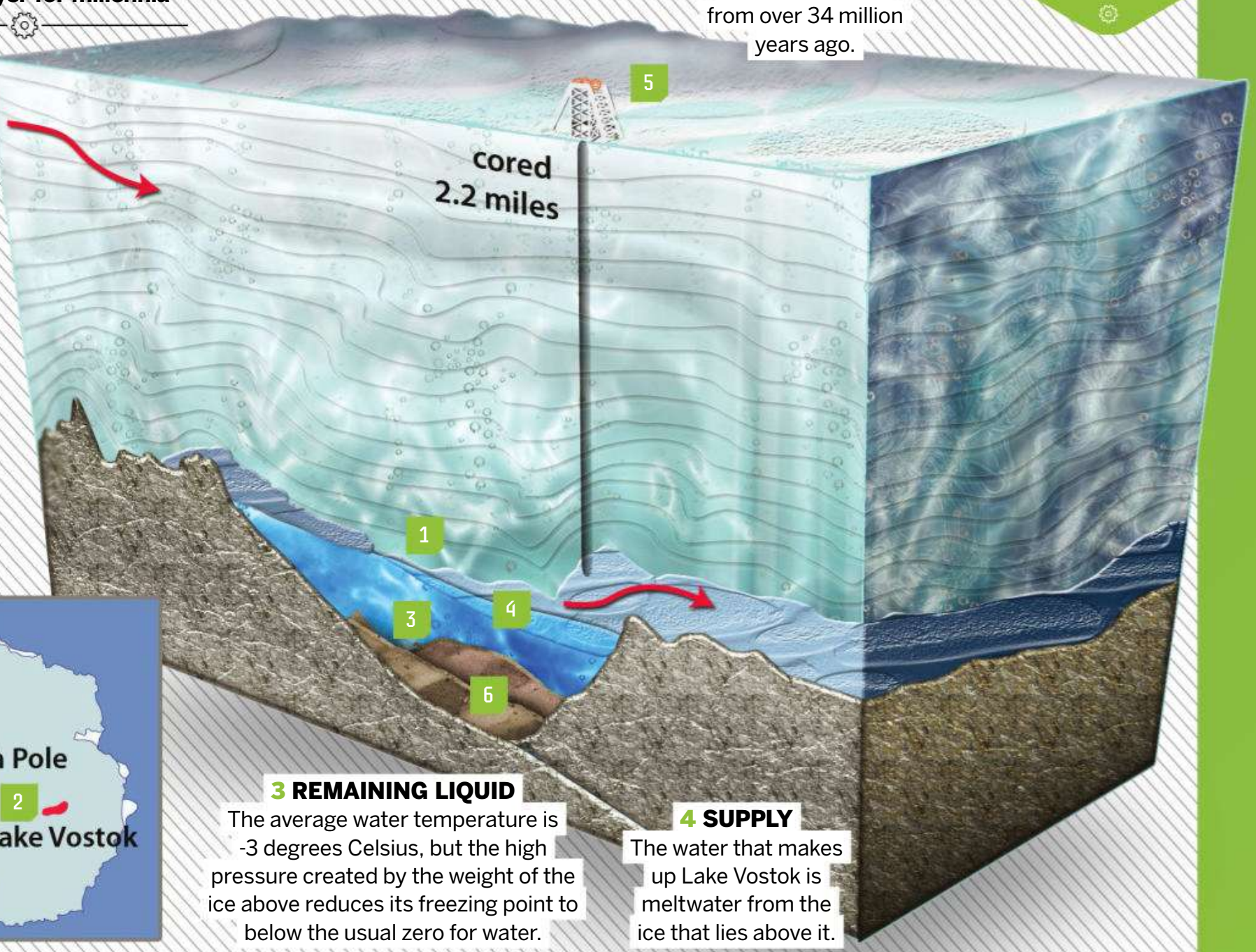
1 THICK ICE
Lake Vostok is concealed by 2.5 miles of Antarctica's frozen ice.

2 LAKE SIZE
Lake Vostok spans 150 miles in length, is 31 miles wide and at its deepest point is around 1,000 metres deep.

5 LAKE VOSTOK RESEARCH STATION
Russian scientists cored a hole 3,769 metres into the ice to retrieve samples of the subglacial lake.

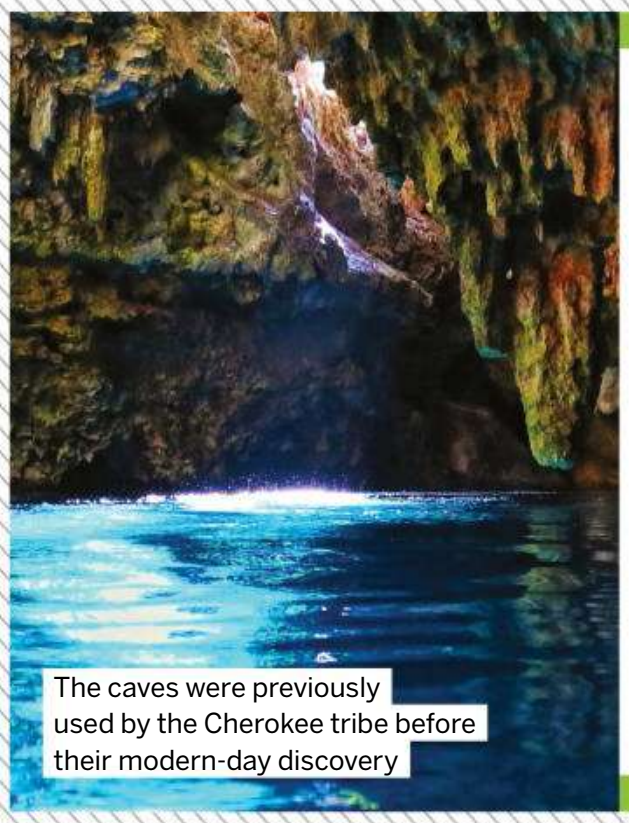
6 LAKE SEDIMENT
If the sediment below Lake Vostok wasn't accumulated from meltwater, it could be preglacial water from over 34 million years ago.

Did you know?
Lake Vostok was likely formed by volcanic activity melting the ice



3 REMAINING LIQUID
The average water temperature is -3 degrees Celsius, but the high pressure created by the weight of the ice above reduces its freezing point to below the usual zero for water.

4 SUPPLY
The water that makes up Lake Vostok is meltwater from the ice that lies above it.


The caves were previously used by the Cherokee tribe before their modern-day discovery

10 THE LOST SEA

CRAIGHEAD CAVERNS, TENNESSEE

Part of what makes underground worlds so compelling is their secrecy. Without in-depth exploration, many of Earth's hidden wonders would never be known, and many places still remain unseen by humans today. In 1905, a 13-year-old boy named Ben Sands was doing some exploration of his own when he squeezed himself into a tight gap in the ground and emerged in a giant water-filled cave.

The Lost Sea is one of the largest underground lakes in the world, with its visible water covering an area of over 6.1 square miles. Despite the modern discovery of this large lake, the young teenager wasn't the cave's first visitor. Earlier settlers had found the expansive lake prior to Sands' discovery and there were rumours surrounding its existence. Upon inspection of the cave's rock, the tracks of a Pleistocene era jaguar were discovered, proving that this underground marvel was visited by animals around 20,000 years ago.

© Alamy / Shutterstock

WHAT ARE HORSE HOOVES FOR?

These hard, living structures keep horses alive and running

WORDS **AILSA HARVEY**

Horses are equipped with lean legs and powerful muscles that can propel them at speeds of up to 55 miles per hour. Their hooves also assist their athletic abilities.

Horses walk on their tiptoes, as the pointed end of their feet bones face towards the ground. To protect their delicate bones, their feet develop hard structures called hooves. A horse feels the ground slightly through their hooves, but much of the structure lacks nerves and therefore sensitivity. This protects the feet and limits pain as they stampede through different terrain. Although the hooves serve as natural shoes to wild horses, most domestic horses are fitted with metal shoes. This is because these horses are ridden more frequently along harder terrain than wild horses are used to. The shoes are attached to the hardest part of the hooves, where there are no nerve endings and no pain is felt.

Did you know?

Horses grow a new hoof every year

Horse shoes protect hooves from damage on hard surfaces like roads

Foals are usually capable of standing within an hour of birth

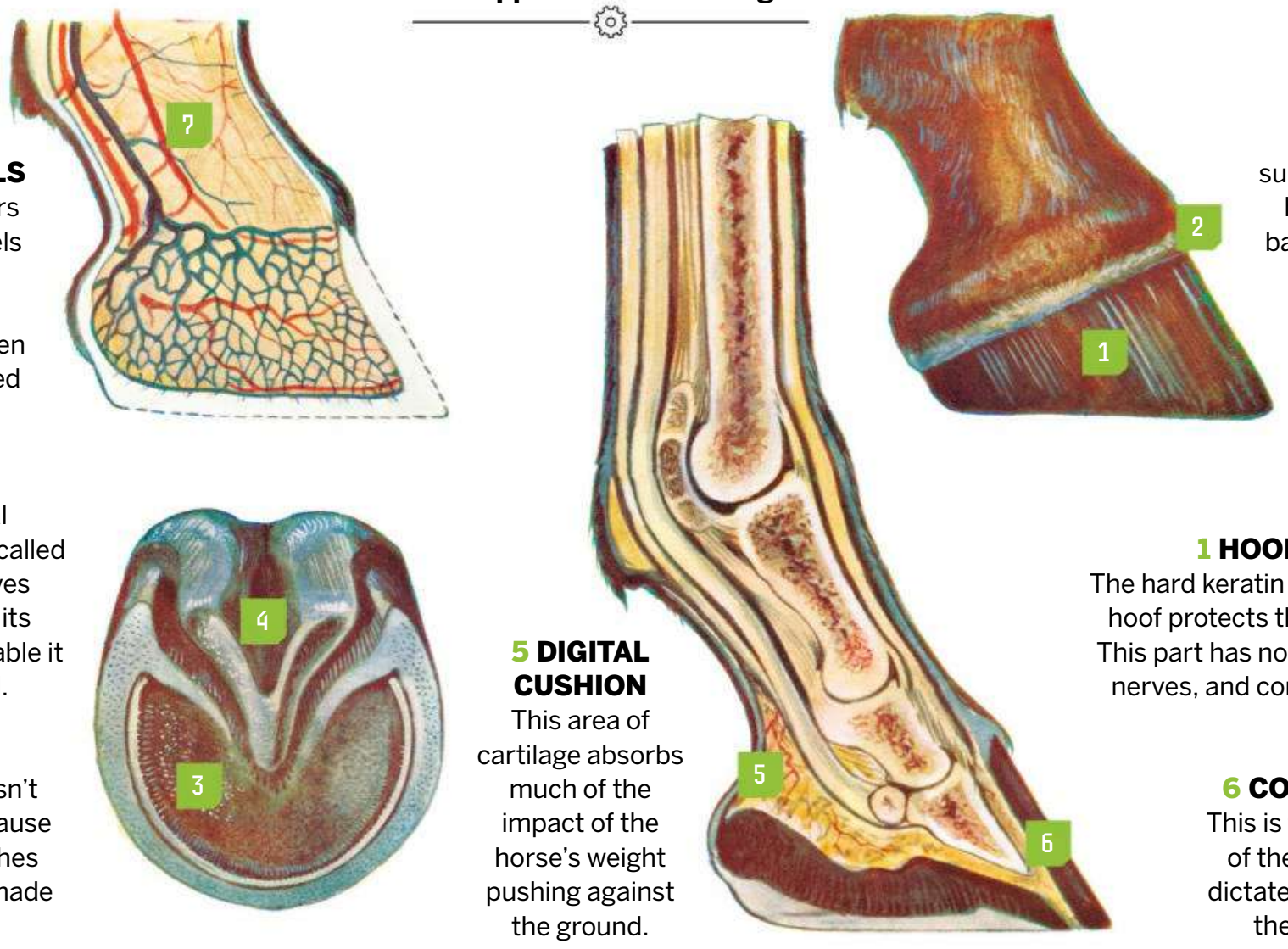
EVOLVING WITH AGE

Baby horses, called foals, are born with irregularly shaped hooves called eponychium – also known as hoof capsules – at the end of each leg. Instead of having fully formed feet, foals have lots of rubbery finger-like extensions hanging from the ends of their solid hooves. These cover the hard edges of their hooves, which are almost fully formed to enable foals to begin walking quickly, and in the wild, reduce the likelihood of them falling victim to predators.

Female horses can't give birth to their babies safely without this protective tissue, as the hard hooves would injure them. When the foal begins to walk, the hoof capsules are quickly shed and their ends harden into fully formed hooves.

HOOF ANATOMY

What's inside these four small structures that supports a horse's weight?



7 BLOOD VESSELS
When the hoof bears weight, blood vessels are compressed. When the hoof is raised, the veins open and blood is pumped up the leg.

4 FROG
This tough central V-shaped structure is called the "frog". The nerves inform the horse of its foot's position and enable it to feel the ground.

3 SOLE
Most of the sole doesn't touch the ground because the inner section arches upwards. The sole is made of softer keratin.

5 DIGITAL CUSHION
This area of cartilage absorbs much of the impact of the horse's weight pushing against the ground.

2 CORONARY BAND
This tough band above the hoof supplies nutrients for hoof growth. The band contains many blood vessels.

1 HOOF WALL
The hard keratin outer layer of the hoof protects the softer tissue. This part has no blood vessels or nerves, and continually grows.

6 COFFIN BONE
This is the main bone of the hoof, which dictates the shape of the hoof wall.

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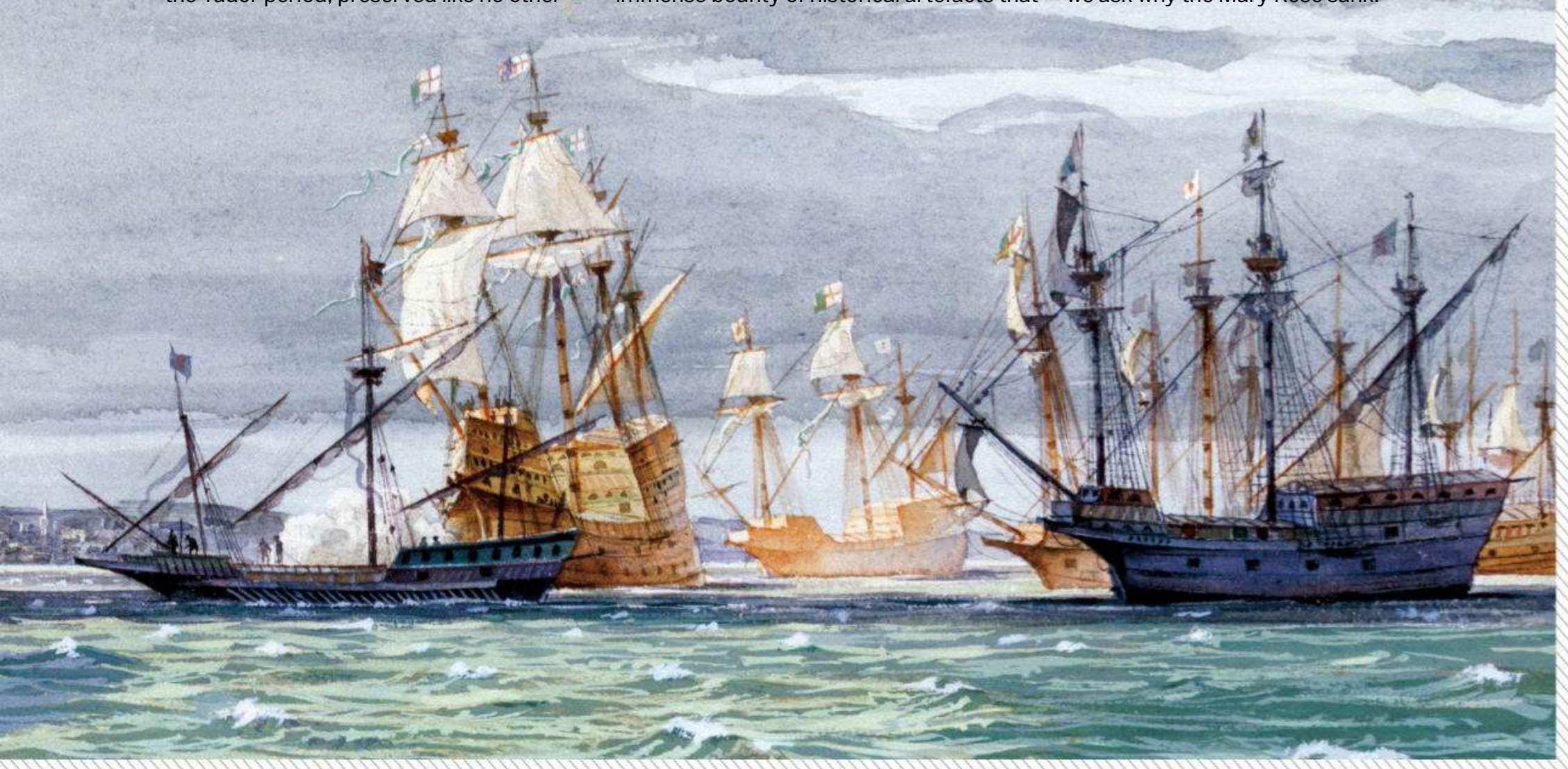
DID YOU KNOW? The Mary Rose was built in Portsmouth, which is also where its remains reside today

SECRETS OF THE MARY ROSE

This famed Tudor ship was Henry VIII's pet project, but why did his fleet's flagship sink suddenly in the Solent?

WORDS **ALEX HOSKINS**

As the last vestiges of the Mary Rose were consumed by the very sea it sought to conquer, the men who would sink to the bottom of the ocean with it couldn't have known that they were to become part of one of the greatest archaeological sites of the Tudor period, preserved like no other for historians of the 20th century to marvel at and analyse for decades. This particular disaster, unexpected and perhaps entirely unnecessary, was rare – the loss of life may have seemed futile, but without it we might have a very different understanding of the Tudor period. But it's not only for its immense bounty of historical artefacts that the Mary Rose has endured as one of England's – and perhaps the world's – most notable shipwrecks. It's also, as ever, the mysteries surrounding its story that have seen it remain a point of fascination for history enthusiasts and experts alike. There's plenty we can't be sure of when we ask why the Mary Rose sank.



What we do know is that the Mary Rose was commissioned by Henry VIII as part of a new navy. He had inherited a rather measly fleet, setting about improving it for the many battles that lay ahead with sea ships known as carracks – the Mary Rose and another commission, Peter Pomegranate. Historians still debate exactly who the boat was named after – and if it was named after a person at all, as this was not the trend at the time. Popular belief often sides with Henry's sister, Mary Tudor, while it's generally considered more likely the name was a tribute to the Virgin Mary, known at the time as the 'Mystic Rose'. This also chimes well with the naming of Peter Pomegranate, as the pomegranate is a symbol of resurrection and eternal life, often associated with Jesus. The fruit is even shown in the hand of Jesus in some depictions of the Madonna and Child. The pomegranate was also a symbol of the house of Aragon, which was certainly a consideration when Henry chose the name for the boat, as he was married to Catherine of Aragon. When they divorced, Henry renamed Peter Pomegranate as Peter.

However, the boat's name is not the only source of mystery. The end of the Mary Rose came suddenly on 19 July 1545. Having survived a glittering career of three French wars from 1512 to 1545 – with rest and restoration in between – the Mary Rose was sunk dramatically in the Battle of the Solent, much to the surprise and delight of the French. It was a stacked battle, the French fleet numbering 128 ships, while Henry's was just 80. But it was soon to be down one notable ship.

The French account of the battle tells that on the morning of the fateful 19 July, after two days of battle with no real loss to either side, French ships made an attempt to lure the English out of their relative safety in the Solent to come within closer range of the French galleys. The weather had been calm all day, and yet suddenly, the Mary Rose began to sink. If we look to the English records, the events played out differently: Henry VIII had been dining with Admiral Viscount Lisle on the fleet's pride and joy, Henry Grace à Dieu, the night before the sinking. At dinner, Henry bestowed the Mary Rose upon George Carew, which, with the Mary Rose being the fleet's second-largest vessel after Henry Grace à Dieu, promoted him to the heady heights of vice admiral of the fleet. Little could he or anyone else know, he would soon be in charge of a ship that was doomed to failure. Some accounts claim that Henry VIII looked on from Southsea Castle as the Mary Rose sank – we can only imagine today how it would feel to see the flagship of your fleet sink, without discernible reason.

Whichever order of events is correct, whether French or English, the question remains: what was the cause of this sudden trajectory towards the abyss? There are four main theories for the ship and crew's shocking demise. The first of these stems from the same French accounts referenced previously, in which one lone French cavalry officer claimed that the ship had been sunk by an onslaught from French guns that had been in the process of trying to goad the English into coming further away from the shallow water at Spitbank. The likelihood of this would depend upon the position of the hit: if it were a cannonball low in the ship's hull, water would inevitably leak into the vessel, causing an upset to the balance and resulting in the ship toppling over.

Another theory is that the vessel had been overloaded, either with guns, men or both. During improvement works while it was kept in reserve between 1522 and 1535, the ship gained an extra capacity of some 100 tonnes. It was caulked and made as new and was fitted with extra bracing, indicating that the Mary Rose was expected to carry heavier loads in the future. We can't know for sure exactly what changes were made, but it has been suggested that extra gun ports were also cut to allow greater fire power. However, it's generally considered unlikely that overloading with guns could be the reason for the topple, as the ship had successfully made the journey from London.

Did you know?

Grace à Dieu means 'thanks be to god'

The overloading of soldiers is a much more likely contributing factor in the disaster. The ship was built to hold 400 men, but reports state that 700 were aboard at the time of sinking. Imagining the scenes of panic among the crew and soldiers as the boat began to sink suddenly, packed like sardines with no escape route, is truly sobering. For the underwater archaeologists who uncovered the bodies of many of those men on board four centuries later – the wreck was rediscovered in 1836 by a local fisherman, and in 1965 a local diving group led by a diver called Alexander McKee identified the first part of the ship's wreck – it must have been a shocking, while certainly exciting, sight to behold.

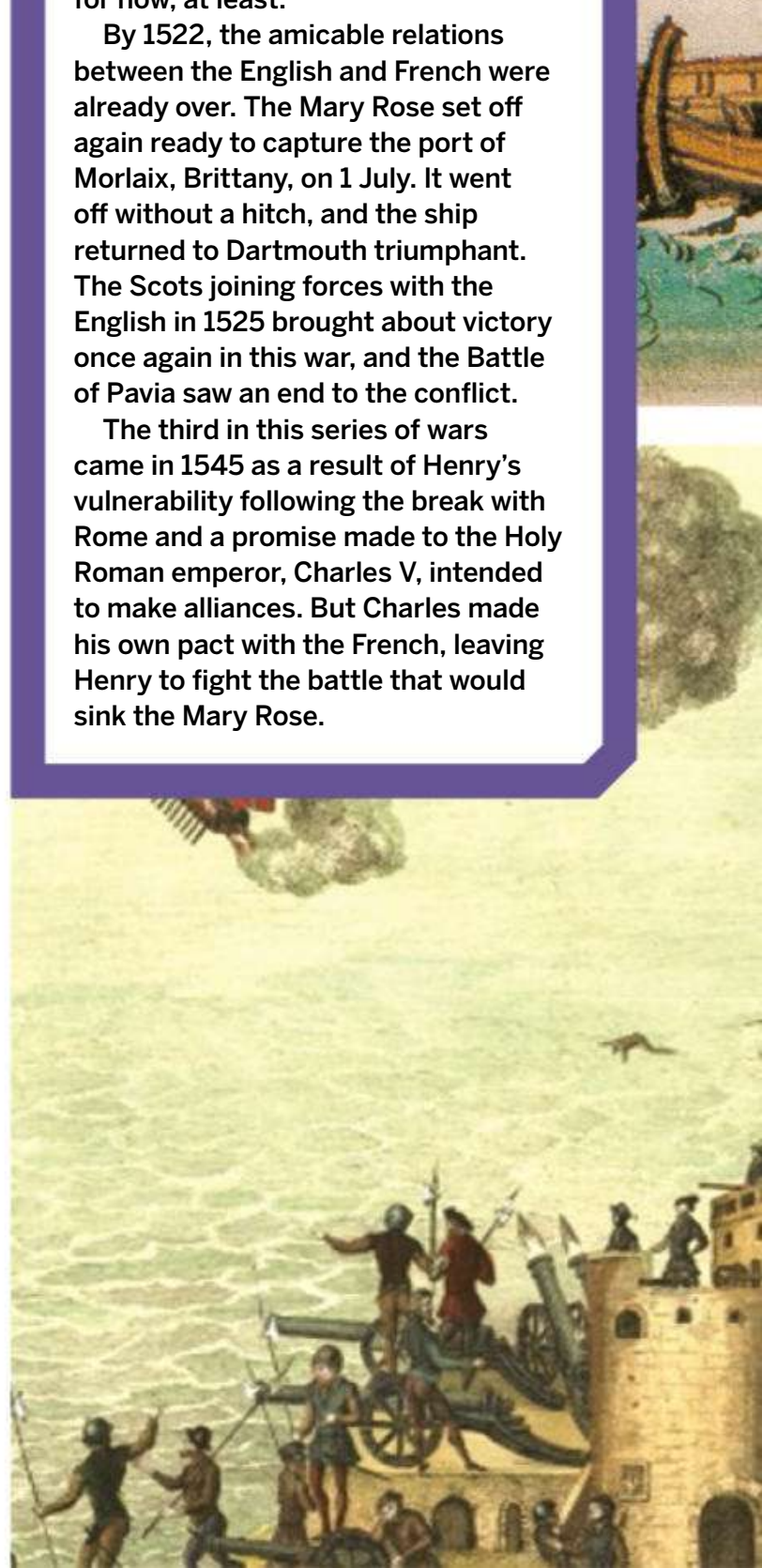
A catastrophic case of human error is cited as another possible explanation for the ship's end – with a crew of 700 men, it's not beyond the realms of possibility that in the heat of battle, a crew member could make a fatal mistake, perhaps leaving open a spot that should have been defended or failing to close a gun port. A final theory, which seems almost too simple to have claimed the lives of so many, is that a rogue gust of wind caught the ship while it was in a vulnerable position, turning to make use of the guns on its other side. Whichever is true, we do know that after the initial tipping of the ship, seawater gushed in through the gun ports, sealing the fate of the ship and its men once and for all.

THREE WARS WITH THE FRENCH

The reason for the Mary Rose's outing on the Solent was a strategic battle – its last in a series of three – against the French. The first had begun in 1512, led by Sir Edward Howard, lord high admiral of Henry's fleet, with the Mary Rose as his flagship. The ship had raided Brittany, with 12 Breton ships captured. Upon returning to Southampton following this triumph, Henry VIII graced the ship with his presence, visiting briefly before it sailed out again to Brest, to the Battle of Saint-Mathieu. It was by all accounts another success. The Mary Rose was a formidable ship at the start of its career. Following this, the vessel was involved in skirmishes and played its part in the Battle of Flodden Field, carrying troops to Newcastle. In the autumn of 1513, Henry's sister Mary was married to the King of France, Louis XII, ending the wars... for now, at least.

By 1522, the amicable relations between the English and French were already over. The Mary Rose set off again ready to capture the port of Morlaix, Brittany, on 1 July. It went off without a hitch, and the ship returned to Dartmouth triumphant. The Scots joining forces with the English in 1525 brought about victory once again in this war, and the Battle of Pavia saw an end to the conflict.

The third in this series of wars came in 1545 as a result of Henry's vulnerability following the break with Rome and a promise made to the Holy Roman emperor, Charles V, intended to make alliances. But Charles made his own pact with the French, leaving Henry to fight the battle that would sink the Mary Rose.



DID YOU KNOW? The ship was launched in July 1511

The Mary Rose as depicted in the Anthony Roll, a record of the Tudor navy of the 1540s

"After the initial tipping of the ship, seawater gushed in through the gun ports, sealing the fate of the ship and its men once and for all"

An engraving showing the sinking of the Mary Rose, based on an original painted between 1545 and 1548

A portrait of Henry VIII near the time of his coronation – and when he commissioned the Mary Rose

INSIDE THE MARY ROSE

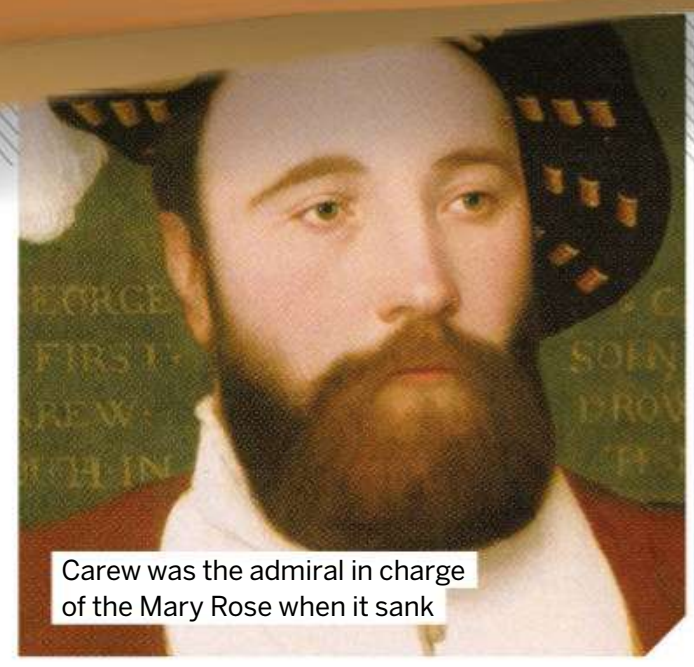
The raising of the Mary Rose from the depths of the Solent has provided archaeologists and historians with incredible knowledge about the running of a Tudor ship. Items discovered, such as longbows and woodworking tools, have also provided an insight into the lives of the individuals that went down with the vessel

1 GUNS
Present in various theories for the ship's sinking, the ship's gun ports allowed the gunners to load and shoot cannonballs.

2 ARCHERS
We know that there were several archers on board from the number of longbows found and the changes in bone structure on their remains.

3 THE MASTER GUNNER
One set of remains was identified as the master gunner, displaying a compacted lower spine following years of moving and loading heavy guns.

4 KITCHEN
Remains of what is thought to be the ship's cook were found near the kitchen, along with a ladle, knives and spoon.


Carew was the admiral in charge of the Mary Rose when it sank

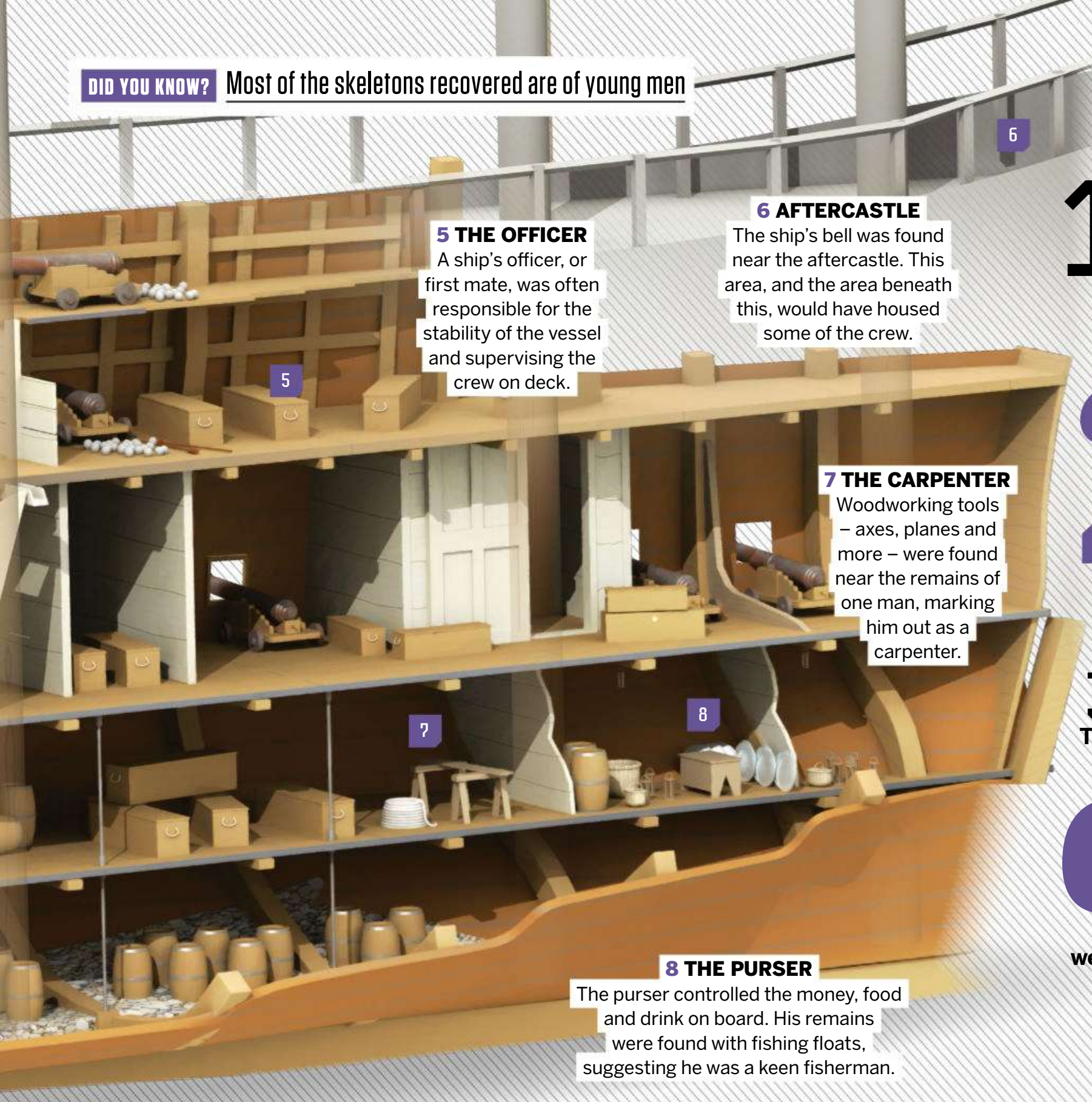
Dr Peter Marsden, a historian and maritime archaeologist specialising in Tudor ships and editor of the book *Mary Rose: Your Noblest Shippe*, which examines what we know about the ship and its structure, considers that the most likely theory is also the most tantalisingly straightforward. "It seems that the reason given for the sinking in 1545 applies. It was simply that on a day of a quiet breeze, the ship had its gun port lids open, having just fired at a French warship, when an unexpected gust of wind heeled it over and it flooded," Marsden explains. This is in line with a rare eyewitness account of the tragedy, which reported that the ship had fired all of its guns and was turning in order to use the guns on the opposing side when it was ambushed by an unexpected gust.

However, Marsden is also keen to consider the impact of communication and possible human error in the events leading up to the tragedy at sea: "It could also be that having many foreign nationals who could not speak English on board added to the problem in that they did not understand orders given in English," Marsden tells us, bringing to light another factor that very likely contributed to the disastrous sinking.

Analyses of the skeletons of the bodies found with the Mary Rose revealed that some of the men aboard were not British, but of Mediterranean or continental European extraction. This could have caused a fatal language barrier that made orders much more difficult to follow for the seamen. However, analyses also suggested that the majority of the men hailed from England's West Country. It's claimed that the admiral of the Mary Rose, Sir George Carew, cried out during the chaos that he was in charge of the "sort of knaves I cannot rule," hinting at disobedience and perhaps incompetence on board the ship.

The picture this paints of the last hours of the men on board is one of chaos, panic and hopelessness. A picture of a crew sunk by their own disobedience and a general lack of understanding between the crew members on board. Levels of illiteracy were perhaps surprisingly high among men at this time, and particularly among the ambitious and somewhat 'upwardly mobile' profession of sailing. About 20 per cent of the male

DID YOU KNOW? Most of the skeletons recovered are of young men



5 THE OFFICER
A ship's officer, or first mate, was often responsible for the stability of the vessel and supervising the crew on deck.

6 AFTERCASTLE
The ship's bell was found near the aftercastle. This area, and the area beneath this, would have housed some of the crew.

7 THE CARPENTER
Woodworking tools – axes, planes and more – were found near the remains of one man, marking him out as a carpenter.

8 THE PURSER
The purser controlled the money, food and drink on board. His remains were found with fishing floats, suggesting he was a keen fisherman.

10,000
Approximate number of artefacts found on the shipwreck

25
Estimated number of crew members that survived

34 YEARS
The Mary Rose served as Henry VIII's flagship

600
Tonnes the Mary Rose weighed when it was made

"The Mary Rose came just before a watershed change for the design of seaships"

population was literate, according to a study of education when Elizabeth I took the throne in 1558. The discovery of artefacts found on board bearing letters – for example a knife handle and a trencher bearing the letter 'W' and a spoon bearing a reversed 'N' – goes further to suggest that the men on board were at least able to read the alphabet. As is often the issue with drawing conclusions about the Mary Rose, we cannot truly know the levels of literacy or competence among the crew.

Finally, one last inconvenience would become a catalyst for the ship's demise: "The inefficient and slow system of closing gun port lids forbade making an immediate response to heeling over," says Marsden. Once the water had begun gushing into these open ports, there would be no chance of stopping it – or of stopping the ship from sinking.

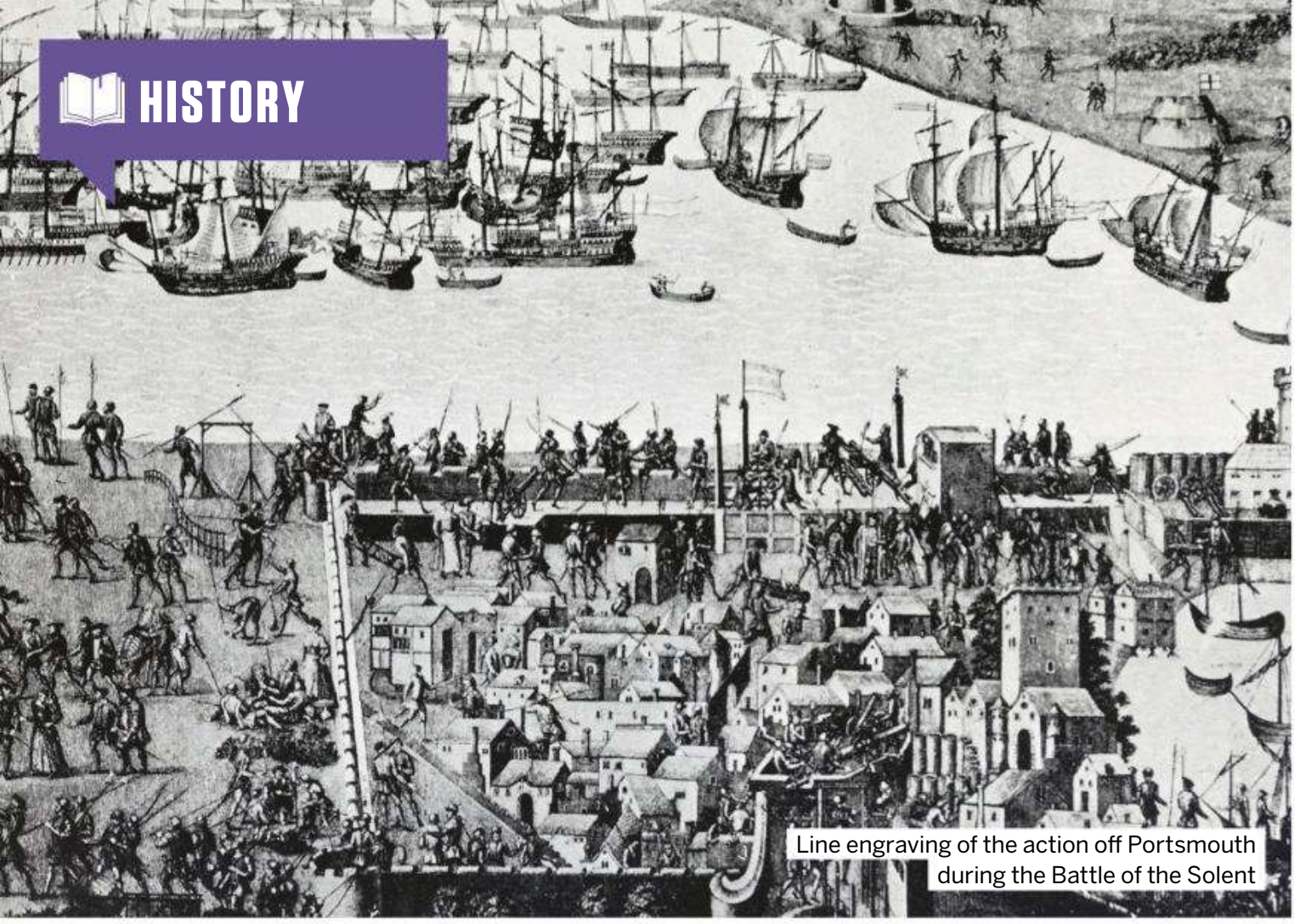
Questions like this one of the fitness of the design of the ship lead to another route of inquiry – should more have been done to make the ship safe for the crew? Was the safety of the crew even a consideration for the war-mongering king or the ship's designers and builders? "Of course, safety was a vital consideration in the period, but as the technology of warfare at sea was pushing ahead quite fast, there were vulnerable areas of danger on board that had not been addressed," explains Marsden.

"For example, the system of opening and closing the gun port lids on the main deck was operated by men pulling ropes on the upper deck, rather than, as in later times, by the main deck gunners themselves, as can be seen on HMS Victory." This would have meant that communication would have been difficult, sight may have been impaired as the gun port lid operators were further from the equipment they were dealing with and any problems would take longer to fix. Considering the prevalence of the slow closing of the gun ports as a cause in the ship's sinking, the operation of lids by men on the main deck was a simple innovation that came far too late for the Mary Rose.

Another cause for concern was the use of what were effectively 'trap doors' located around the ship's deck, inviting disaster as the men went about their daily business. Marsden, who has spent significant time with the wreck's remains, makes the point that "the hatches along the middle of each deck had no gratings, but simply wooden covers. This meant that when a hatch was left open for access, in the dim light below, a man might not notice the hole in the deck and could fall and break a bone." It might seem like an obvious hazard, particularly by today's highly regulated health-and-safety standards, but in the 16th century it was par for the course.

However, things were soon to change. "There were other problems, but shortly after the

© Adrian Mann



Line engraving of the action off Portsmouth during the Battle of the Solent

The salvage of the Mary Rose was a truly momentous occasion

Mary Rose, which was a carrack, sank, a new type of warship design was introduced – the galleon. This solved many of the problems," Marsden tells us. The galleon improved upon the carrack in many ways – carracks were wide and unwieldy to steer by comparison, while galleons were narrower and longer, which contributed towards making their handling much smoother. Carracks were also most often designed with 'castles' at – or even overhanging – the bow and stern of the ship, which were raised areas above the deck and were used for work or combat. Galleons, on the other hand, are flush-decked, with any castles located further into the deck area. This allows for a longer, triangular stern, making them more aerodynamic and easy to steer.

As the Mary Rose came just before a watershed change for the design of seaships, it's incredibly useful for archaeological purposes. It's almost unique in its level of preservation, and in the fact that it was raised from the seabed in 1982 and has been diligently preserved ever since. Its proximity to the English shore and its impressive levels of underwater preservation make it perhaps our most comprehensive insight into Tudor life, and life at sea, in the 16th century.

Did you know?

Prune, pea and peppercorn remains have been found

While there's plenty of mystery surrounding the ship itself, it has also helped demystify a great many aspects of the period for historians. As all of the men aboard died on the same day, for the same reason, it provides a rare snapshot of a particular set of people – and in this case a particular profession – at a specific time. Their dental remains have also been incredibly useful for creating a fuller picture of what people ate at the time – one set even had traces of seeds that allowed analysts a specific view into what one man ate on the very day that he died.

Inspecting the remains to this degree may seem somewhat intrusive, disturbing the earthly remains of hundreds of the men who sank with their ship and likely expected to decompose at the bottom of the sea for eternity. But as with most archaeological endeavours, the results arguably outweigh any ethical doubts. 92 of the skeletons found were almost complete, giving unprecedented insight into the physique of seamen of this time period.

And analyses haven't slowed by any means in the four decades following the raising of the wreck: researchers continue to look into the blood groups, DNA information and the bone characteristics of the remains today. In doing so, they have identified the remains of the ship's archers through identifying a particular bone condition. Members of the gun crew have been identified by ossification – new bone grown later in life as a result of heavy work – and the purser was characterised by the chest of gold and silver coins he was trapped in his cabin with when the ship went down.

Marsden understands well the significance of the archaeological findings on the Mary Rose. "The whole collection gives us a unique view of life on board one of the largest ships of the early permanent Royal Navy," he describes.

'HATCH', THE DOG ON DECK

The prevalence of rats on a Tudor ship called for a domesticated animal to keep the numbers in check. While it may traditionally be thought of as a cat's job, the Mary Rose and other ships employed a dog. We know this as the remains of the animal, nicknamed 'Hatch', were found with the ship. Rats are often too big for cats to catch and kill, and those aboard ships were notoriously fierce, making dogs a far more suitable choice. To add to this, Pope Innocent VIII had declared cats unholy in 1484 as a result of their reputation as companions for witches, which contributed to their being considered 'unlucky'. This opinion died out in England some 200 years later.

Analysis revealed the dog was male and an early form of terrier – though breeds as we know them now would not have existed in the same way at this time. He was between 18 months and two years old and had a brown coat. He was by some way the youngest member of the crew, though some of the remains were identified as being 13 years old.

To determine these details about the ship's canine, DNA was taken from one of Hatch's teeth and analysed by experts from the University of Portsmouth; the Royal Zoological Society of Scotland; the Royal Institute of Technology, Sweden; King's College London Dental Institute; Durham University and the Mary Rose Trust. Researchers also discovered that Hatch had suffered from a hereditary disease called hyperuricosuria, a defect that causes kidney and bladder stones. It was previously thought to be the result of inbreeding in modern breeds, but this may be evidence of its prevalence before the intensive breeding of dogs.

DID YOU KNOW? There were 27,831 dives to the Mary Rose during the excavation project

A collection of domestic artefacts recovered from the Mary Rose

But which of the finds does he think is the most illuminating? His choice highlights a particularly fascinating conundrum in identifying the remains of a specific person aboard the doomed vessel: "If you really push me to find one item more exciting than the rest, it's a group of silk buttons found with a skeleton in the collapsed aftercastle. Only noblemen were allowed by law to wear silk costumes, so it seems likely that the remains of a nobleman were found." The proximity of the buttons to the remains almost entirely marks them out as belonging to each other, and so it would indicate that the skeleton is that of one of the only men aboard that we can actually name today. "Only two are historically recorded as being on board: Sir George Carew and Sir Roger Grenville," Marsden tells us. "Maybe a DNA study will in future tell us exactly who he was – as was done to identify King Richard III."

One of the most significant finds on the wreck was a collection of 137 complete longbows and thousands of arrows – the first such examples to be found intact – offering military historians a startling insight into the importance of longbows and archers in warfare at the time. Analyses of bones revealed that some of the men had developed a bone condition called os acromiale, which affects the shoulders and is still found in modern professional archers, so the remains displaying this condition can fairly certainly be identified as archers on the ship.

In their quest to further understand the use of longbows aboard the Mary Rose, scientists and historians – including the well-known English actor Robert Hardy, as the country's most experienced longbow expert – performed many tests on some of the longbows that were found preserved, testing their flexibility and force to breaking point in some cases. With such a large number of unprecedented exhibits, they were able to fully test the capabilities of this Tudor weapon without too much concern for breaking a specimen in the name of research, finding that the weapons had draw weights of up to an incredible 82 kilograms.

"One of the most significant finds on the wreck was a collection of 137 complete longbows and thousands of arrows"

It's this sort of discovery – of which there have been so many since the ship was raised in 1982 – which makes the Mary Rose such a fantastic historical paradox. Never has a shipwreck answered as many questions about the period it sailed in as the Mary Rose, nor has any shipwreck left quite so many mysteries unsolved. While it may not have been much comfort to the men who died, seemingly without real cause and perhaps at the mercy of a gust of wind, the passage of time has made their deaths remarkable indeed. Without them, we might have a very different picture of the lives of 16th-century seamen and Tudor life as a whole.

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HOW SUNDIALS TELL TIME

These ancient time-keeping devices keep track of Earth's movements around the Sun

WORDS **SCOTT DUTFIELD**

Humans have used the Sun to monitor the passing of time for thousands of years. For example, Stonehenge is believed to have been erected around 2,500 BCE, constructed in such a way that each stone aligns with the Sun's rise during the summer solstice and the sunsets of the winter solstice. However, like so many other technological inventions, the timekeeping sundial seems to have emerged from the minds of ancient Egyptians. The first evidence of a sundial dates back to around 1,500 BCE and was composed in two parts of an L-shaped shadow-casting device to determine the time of day. Over time, different versions of the sundial emerged, such as the ancient Greek hemispherical sundial around 280 BCE and the portable sundials created in Rome around 164 BCE. By the 8th century BCE, more accurate shadow-clocks that you might recognise today were commonly used.

As Earth rotates on its axis, the Sun appears to move across the sky, rising in the east and setting in the west. Along its journey, the Sun's light beats down over the world and casts shadows in places it can't reach. Taking advantage of light's inability to pass through solid objects, sundials use the shadow of a central stick, called a gnomon, to pan across a series of numbers, like a clock face, to indicate what time it is based on the Sun's position in the sky.

Did you know?

Iceland gets four to five hours of daily sunlight in winter

There are, however, several criteria a sundial has to meet before it can accurately tell time, so it's not always as simple as pressing a stick in the ground and surrounding it with stones. For a sundial to accurately tell the time, the gnomon needs to align with Earth's vertical axis, which is tilted to 23.5 degrees, and point either truth north or true south depending on which side of the equator it's on. The gnomon is positioned on the dial plate at an angle that matches Earth's axis, which is also equal to the latitude of its location. For example, in Europe, sundial gnomons are placed at an angle of between 40 and 60 degrees on a horizontal dial plate.

CLOCKING IN

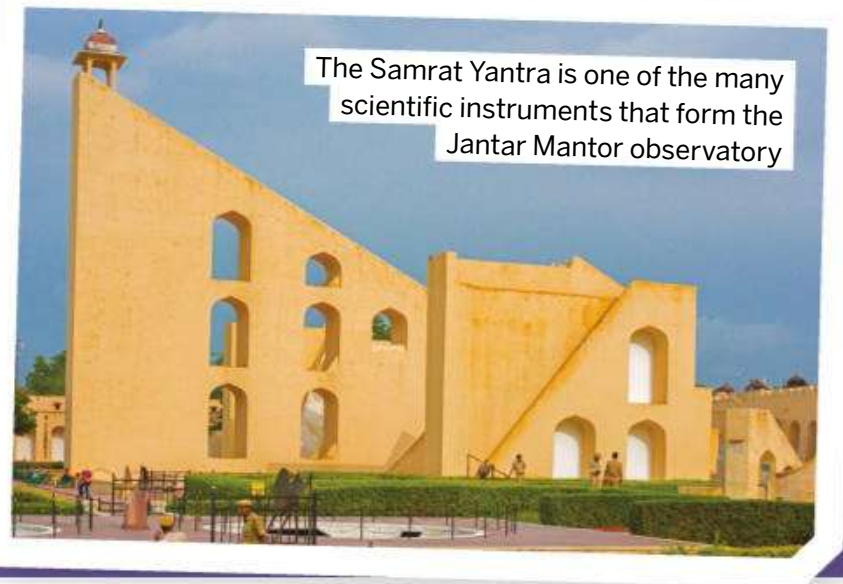
Measuring the passge of time by keeping tabs on Earth's rotation

6 PATH OF THE SUN
As Earth rotates, the Sun passes through the sky, rising in the east and setting in the west.

5 ANGLE
The angle that a gnomon sits on a sundial should correlate with the latitude of where it's placed. For example, in the UK a gnomon is angled around 52 degrees.

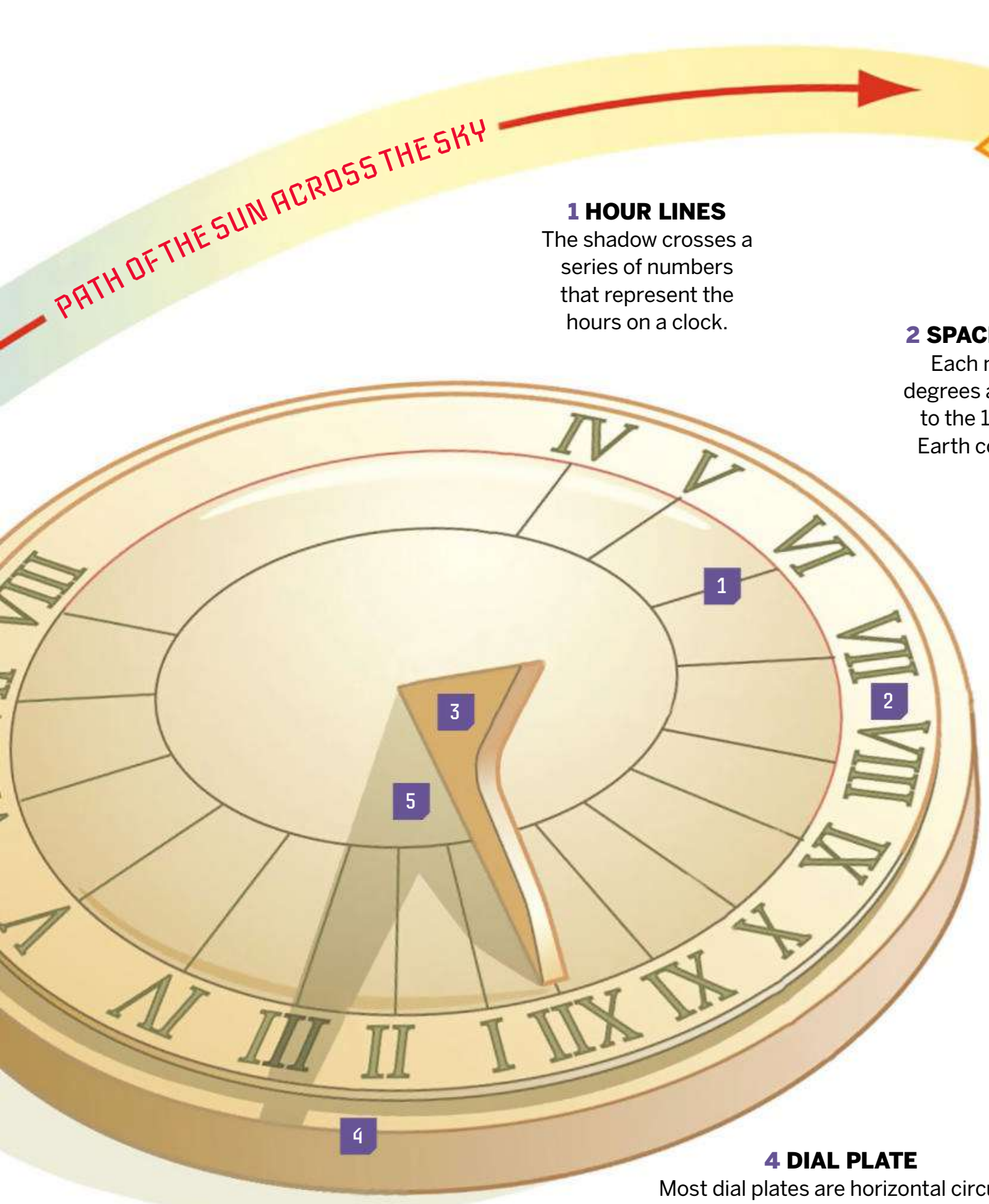
GIANT SUNDIAL

When you think of a sundial, the image of a small, sun-drenched ornament at the bottom of the garden might spring to mind. However, in some parts of the world, sundials are enormous structures. The largest sundial in the world is the Samrat Yantra, a 27-metre-tall edifice built in Jaipur, northern India during the 18th century. The gigantic sun clock, also called the 'supreme instrument', is a part of a series of 19 astronomical instruments that form the Jantar Mantor observatory. Made from stone and marble, the Samrat Yantra has a central gnomon in line with Earth's axis and two adjacent quadrants on either side, running parallel with the equator. When the Sun hits the gnomon, a shadow is cast on scales at either quadrant, indicating the time with an accuracy of within two seconds.



The Samrat Yantra is one of the many scientific instruments that form the Jantar Mantor observatory

DID YOU KNOW? At the equator, Earth's surface spins at a speed of 460 metres per second



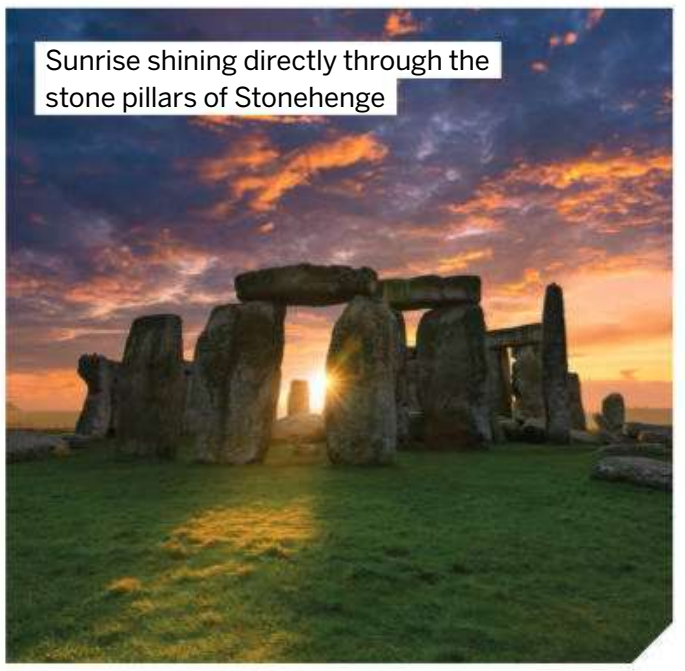
1 HOUR LINES
The shadow crosses a series of numbers that represent the hours on a clock.

2 SPACING THE NUMBERS
Each number is exactly 15 degrees apart, which correlates to the 15 degrees of rotation Earth completes in one hour.

3 GNOMON
The shadow-casting gnomon is angled towards either the true north or true south.

4 DIAL PLATE
Most dial plates are horizontal circular plates, parallel to Earth's axis of rotation. However, there are vertical alternatives that require the gnomon to point to the equator rather than the poles.

An example of a horizontal sundial with its gnomon casting a shadow on a dial plate


Sunrise shining directly through the stone pillars of Stonehenge

SUNDIALS IN SPACE

Distinguishing between colours on the Red Planet can be a tricky business for a space rover when it's trying to take a picture. Therefore, the onboard cameras need to be calibrated so that scientists can see if rocks are really red or not. To do this, NASA has employed an ancient technology to calibrate its cameras: the sundial. In place of the numbers used on a traditional time-telling sundial, a series of colours, such as red, blue, green and yellow, sit around the dial. When sunlight causes the central gnomon to cast a shadow, it points to one of the colours on the dial. Scientists back on Earth make note of what colour is shown on the sundial and use it to colour-correct images that the rover takes.

The 'marsdial' used on the Perseverance rover that's currently on Mars

© Alamy / Getty / NASA/JPL-Caltech/ASU/MSSS/University of Copenhagen

ISAAC NEWTON

The pioneering physicist that got to grips with gravity and set the world in motion

WORDS **SCOTT DUTFIELD**

Above: A painting of Sir Isaac Newton analysing the ray of light

Right: Sir Isaac Newton explained some of the most fundamental forces in physics

Right inset: Newton's apple-induced gravitational epiphany is likely a myth

On Christmas day 1642, Hannah Ayscough and Isaac Newton Sr welcomed their new child into the world. Little did they know at the time that he would grow up to be both a pioneering scientist and the greatest mathematician of his generation. Unfortunately, only three months after his birth, Newton's father, a wealthy farmer, passed away. His mother remarried, at which point Newton was left in the care of his grandmother.

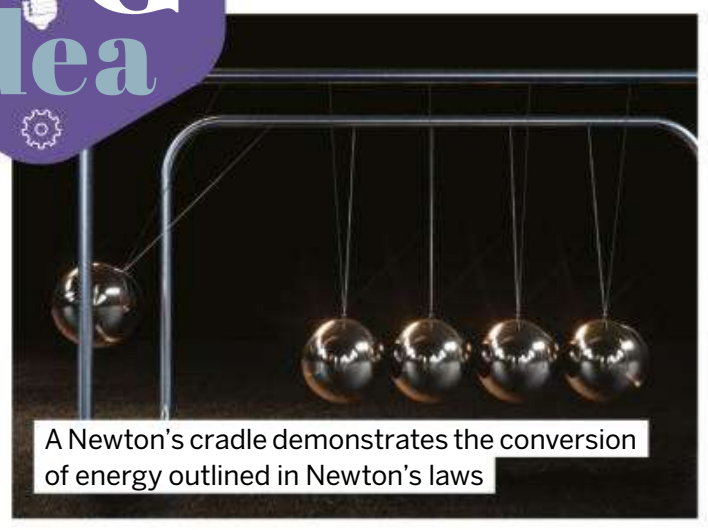
As a child, Newton attended a free grammar school in Grantham, Lincolnshire. However, his school reports were far from complimentary of Newton's academic abilities, describing him as 'idle' and 'inattentive'. Nevertheless, Newton persisted with his education, and in 1661 enrolled at Trinity College, Cambridge, intending to complete a law degree. However, after thumbing through the pages of an astrology book in 1663, Newton's academic journey was changed, and he headed straight for mathematics. In 1665, Newton completed his degree, specialising in mathematics and philosophy.

Throughout his life, Newton made countless contributions to the world of mathematics and the field of physics. One of his first major discoveries involved light. Using a glass prism, Newton was the first person to suggest that light was made up of different rays of colour that came together to form visible light. However, it was his work to uncover the fundamental laws of motion that propelled him into scientific stardom.

Among the many books Newton published during his life, *Principia* outlined the ever-present force of gravity and its ability to pull objects. Newton proposed that the more mass an object had, the stronger the pull of gravity, and the greater the distance between the two, the weaker the attraction between them.

Over time, Newton has become synonymous with a falling apple hitting his head. Long has the story of Newton tending to a sore head been told

The BIG idea



A Newton's cradle demonstrates the conversion of energy outlined in Newton's laws

DISCOVERING THE THREE LAWS OF MOTION

Newton is best remembered for the development of his three laws of motion. The first is Newton's law of inertia, in which every object will remain at rest or in uniform motion unless compelled otherwise by an external force. Then there's the law of acceleration, which defines that a force is equal to the change in the momentum per change in time. When more force is applied to an object, its acceleration increases, but when the mass of the object increases and the force remains the same, its acceleration decreases. Finally, the third law of action and reaction states that every action has an equal and opposite reaction.

5 THINGS TO KNOW ABOUT ISAAC NEWTON

1 NEWTON THE ALCHEMIST
Newton conducted several experiments to convert base metals into precious metals. He even attempted to create a philosopher's stone from mercury.

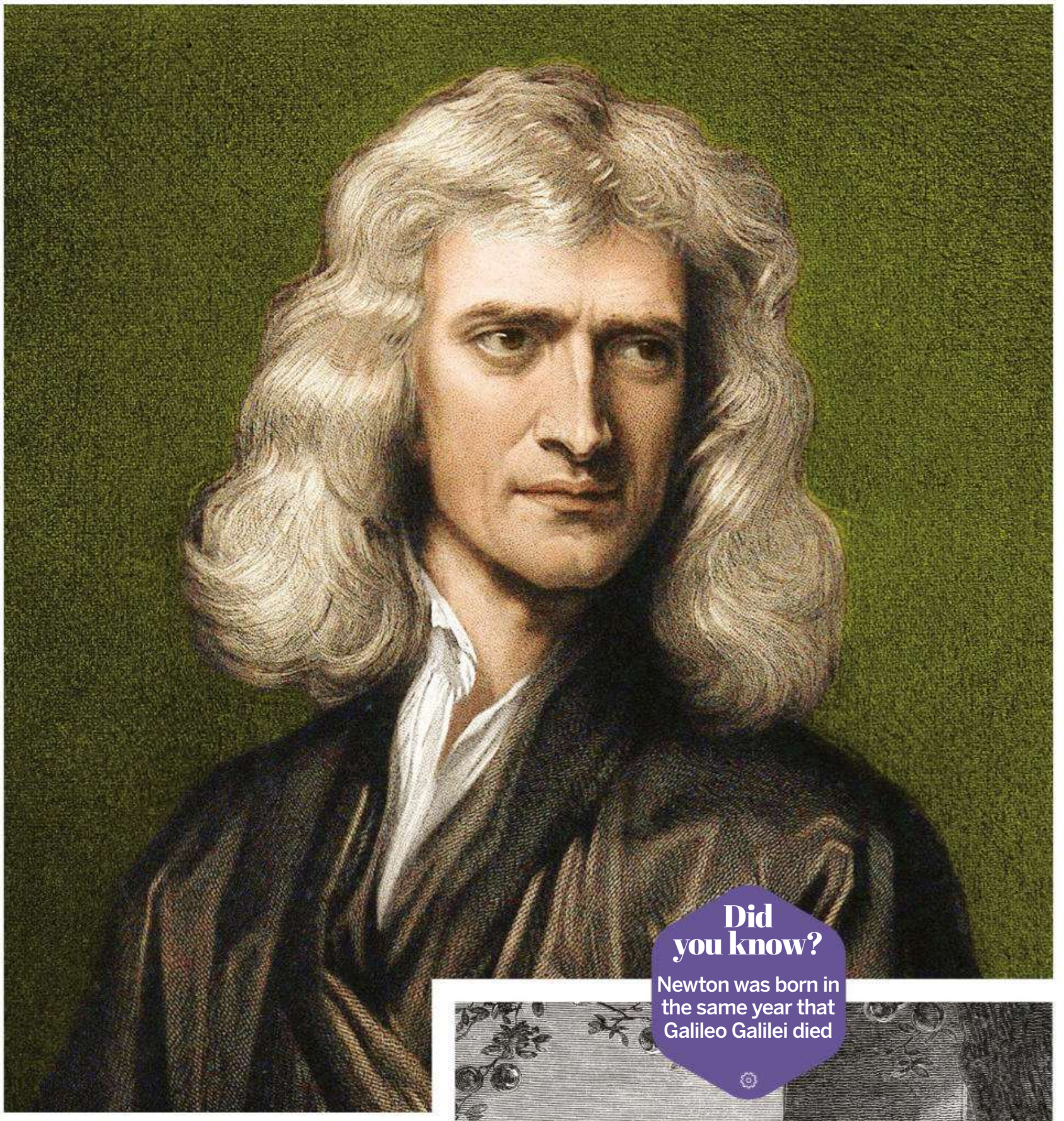
2 HE'S GOT TWO BIRTHDAYS
England used the Julian calendar, which put his birthday as 25 December 1642. However, when the Gregorian calendar was adopted in 1752, his birthday became 4 January 1643.

3 HE ALMOST GAVE HIMSELF A LOBOTOMY
As his own scientific guinea pig, a young Newton inserted a large blunt needle behind his eyeball to study the shape of his eye and measure the pressure exerted by this eyeball.

4 A DOG NEARLY DESTROYED EVERYTHING
Newton's dog Diamond is said to have knocked over a candle and set fire to his papers. Some of these charred notes sold at auction in 2020 for £378,000.

5 A BAD INVESTOR
In 1720, Newton invested £20,000 in the South Sea Company. However, the investment was far from fruitful, and he lost the lot, which would equate to over £3.3 million today.

DID YOU KNOW? The bubonic plague caused Newton to flea Cambridge back to Lincolnshire for two years in 1665



Did you know?

Newton was born in the same year that Galileo Galilei died

as the catalyst for his understanding of the world's forces, particularly gravity. However, this is largely disputed among historians, as the supposed apple accident occurred 20 years before he published his theories on gravity.

However, not all of Newton's ideas were revolutionary. In *Principia*, Newton describes how rarefied vapour from comet tails is pulled into Earth's gravitational grasp and enables the movements of the planet's fluids, along with the "most subtle and useful part of our air, and so much required to sustain the life of all things with us."

At the age of 84, Sir Isaac Newton died peacefully in his sleep at Kensington on 20 March 1727. He was buried in Westminster Abbey eight days later. His white and grey marble monument stands in the nave of Abbey's choir screen and boasts sculptures of Newton lounging surrounded by children using the many instruments, such as telescopes, that are associated with Newton's work.

A LIFE'S WORK

The academic milestones that made Isaac Newton a pioneering mathematician and physicist

1669
Newton first described his reflecting telescope to the Royal Society.

1672
The first of Newton's scientific papers on light and colour was published in the journal *Philosophical Transactions*.

1684
The first work on the subject of calculus, called *Novus methodus*, written by Newton, was published.

1687
Newton published his first book Principia, outlining the laws of motion and the law of universal gravitation.

1703
Newton was elected as the president of the Royal Society.

1704
The first edition of *Opticks: Or, A Treatise of the Reflections*... was published.

1705
Queen Anne knighted him, making him the first scientist to be bestowed this honour.

1707
Arithmetica universalis was published, in which Newton explores the essentials of algebra and geometry.

1728
Newton's work on universal gravitation and its consequences in astronomy was published in *De mundi systemate* (The System of the World).

© Alamy / Getty

HOW TO TAKE OFF VERTICALLY

These aircraft have ditched the runway and can shoot straight up into the sky

WORDS **SCOTT DUTFIELD**

DID YOU KNOW? The largest Russian helicopter is the Mil Mi-26, which weighs 56 tonnes and is 40 metres long

Among the myriad aircraft in the world, there are two main ways to get airborne. There are conventional aeroplanes that combine ground acceleration, a runaway and fixed wings to generate lift and propel them into the air; then there's the aircraft that get straight to the point and rise from the ground vertically. These are known as vertical takeoff and landing (VTOL) aircaft.

The idea of VTOL isn't a novel one; it's not even one that has been dreamt up in the last 100 years. During the 15th century, Leonardo da Vinci, designed a corkscrew-like aircraft that would, in theory, lift straight off the ground. Known as the 'aerial screw' Da Vinci's design used a linen spiral wound around a wooden shaft and spring, driven by four men, to supposedly generate enough lift to get it off the ground. Da Vinci never constructed a model of his spiral helicopter, but scientists are pretty sure that while he was on the right lines, its execution would likely fail. This was mainly because the screw would be too heavy to generate enough thrust to get it airborne.

Although Da Vinci's helicopter designs never made it to the sky, the concept of vertical flight was indeed a success that was achieved by fellow Italian engineer Enrico Forlanini in 1887. Forlanini's invention replaced man-power with a steam engine and instead of a spiral blade, used two counter-rotating propellers. During its first flight, Forlanini's helicopter remained in the air for 20 seconds and reached 13 metres before returning to the ground.

In the footsteps of these two Italian pioneers, countless others have advanced vertical take-off technology and transformed it into an ever-evolving form of transport.

Did you know?

The altitude record for a helicopter flight is 12,954 metres

ROTARY BLADES, JET ENGINES OR BOTH?

There are two ways that aircraft can achieve VTOL, by either using a set of spinning rotary blades or a jet engine pointed to the ground.

Unlike a typical fixed-winged plane, aircraft that use rotary blades, such as helicopters, don't have access to a free source of lift to fly; they have to generate it themselves. Rotary blade vertical take-off relies on Isaac Newton's third law of motion, which states that when object A exerts a force on object B, B will also exert a force that's equal and opposite. For helicopters and drones, their spinning propellers push air downwards generating the force called lift, which is met with the force of gravity. When the amount of lift generated is greater than the force of gravity, the aircraft lifts into the air vertically. When the two forces are equal, the aircraft hovers, and when the amount of lift generated is reduced to less than the pull of gravity, the aircraft lands. The same laws of physics apply to aircraft such as Harrier jets, which use the force generated by their internal combustion engines and redirect it to the ground to

The Hawker Siddeley Harrier on its vertical descent

THE FIRST TAKE OFF

Named after its inventor, the Hawker Siddeley Harrier – also known as the Harrier Jump Jet – was the world's first vertical take-off combat aeroplane. After years of development during the early Sixties, the first Harrier took flight in 1967. Much like the modern F35, the Harrier was capable of STOVL. To achieve this novel feat, the Harrier utilises an equally new piece of technology supplied by Rolls-Royce called the Thrust Measuring Rig, also known as the Flying Bedstead. Using angled jet pipes, this jet engine directed thrust directly towards the ground allowing the aircraft to hover. The Harrier retired from service in the Royal Air Force in 2006, paving the way for the next generation of VTOL fighter jets.

HOVERING

The physics that keep helicopters up in the air

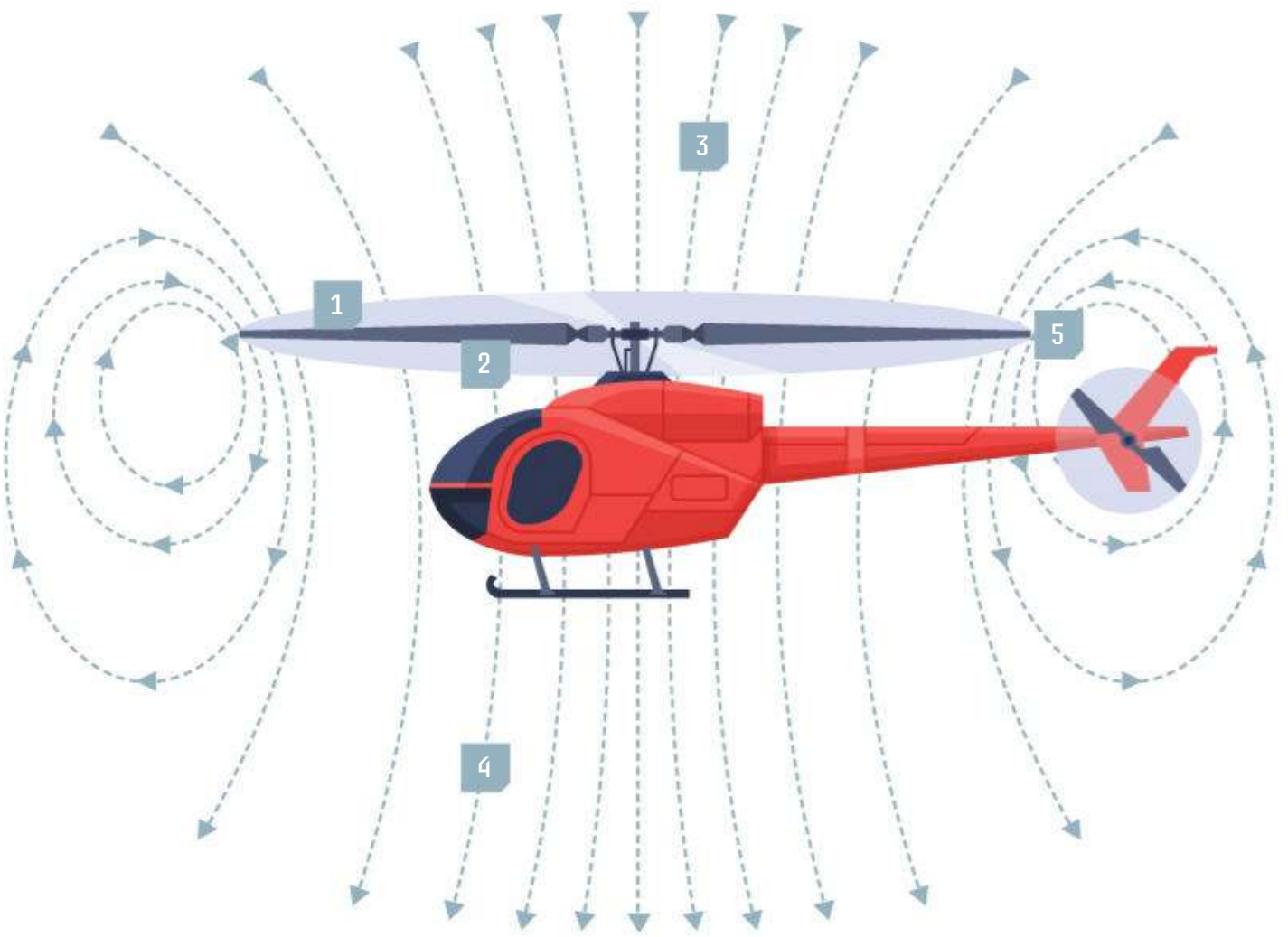
1 SPEED
A typical rotary blade spins at around 450 revolutions per minute.

2 CHANGING PITCH
By changing the orientation of the blades, known as pitch, the helicopter directs more or less air downwards, increasing or decreasing its lift.

3 MOVING DOWNWARDS
As the rotary blades spin, large volumes of air are pulled downwards, generating the lift to keep the helicopter hovering.

4 STRONG WINDS
Beneath the helicopter, wind velocity can reach over 100 miles per hour.

5 BALANCING ACT
For the helicopter to hover, the lift generated by the rotary blades has to equal the weight of the aircraft.



© Alamy / Getty

generate vertical lift, along with some help from some pretty powerful fans.

What would happen if you took the rotary ability of a drone and combined it with the engine power of a fixed-winged plane? You'd have a tiltrotor. Aircraft such as the Bell Boeing V-22 Osprey, an American multi-mission military plane, use a pair of rotating engines that are attached to the end of a fixed wing. During takeoff and landing, the rotary engines are angled horizontally, like a drone. However, during flight the rotary engines are tilted forward for horizontal flight. The fixed wings then utilise lift to stay airborne and the rotary engines to generate thrust to propel it through the air.

PUTTING VTOL TO USE

Without the need for a runway, VTOL has transformed not only the mechanics of aviation, but greatly increased the accessibility of aircraft. From rescue helicopters to delivery drones, VTOL technology makes remote locations and difficult terrain accessible for a whole host of industries. For example, the United Arab Emirates has approved the design of new air taxi stations within the city of Dubai for rotary electric flying taxis to ascend in the next few years.

One area where VTOL has made arguably the most impact is in the military. From fighter jets to surveillance drones, the ability to become airborne in a matter of minutes has been invaluable to the armed forces around the world, in particular via the creation of a family of planes called the F35 Lighting II.

As the creme de la creme of supersonic-capable aircraft, the F35 comes in three variations. The F35A is a conventional takeoff and landing aircraft, the F35C is a carrier-based plane, while the F35B is capable of short take-off and landing (STOVL). Like any other VTOL aircraft, the F35 vertically ascends and descends. However, its vertical take-off is limited in height due to the plane's heavy payload, which is around 27,000 kilograms.

Did you know?

The F35 can reach speeds of over 1,200 miles per hour

The F35B's STOVL abilities are partially thanks to a shaft-driven progression system called LiftFan®, which was provided to the F35's manufacturer Lockheed Martin by Rolls-Royce. Much like the rotary blades of helicopters, the LiftFan drives air downwards, behind the cockpit of the plane, to generate lift. The rest of the F35's STOVL ability comes from the American aerospace manufacturers Pratt & Whitney, who produce the F135 engine. This comes with a nozzle that swivels 90 degrees to redirect the thrust produced by the plane's turbo engine toward the ground. Together, the lift system and the engine work in harmony to get the jet into the air.

F35 TAKEOFF

The systems that generate thrust for vertical ascent

8 AT THE TOUCH OF A BUTTON
For the pilot to engage in STOVL, they need only press a button and the automated system works to redirect thrust and turn on the LiftFan.

1 THE LIFTFAN®
During a hover, two doors open on top of the aircraft and the two counter-rotating fans blow around 9,000 kilogram-force of unheated air downwards.

2 ALMOST EQUAL SPLIT
The air blown down from the LiftFan produces almost half of the downward thrust needed to hover.

DID YOU KNOW? The Harrier Jump Jet can come to a complete stop from 620 miles per hour in just 12 seconds

NEXT GEN TAKEOFF

The American Defense Advanced Research Projects Agency (DARPA) is developing the new generation of military VTOL aircraft in a project known as the AdvaNced airCraft Infrastructure-Less Launch And RecoverY X-Plane (ANCILLARY) programme. Currently, unmanned drone systems require specific infrastructure and pre-existing air bases to launch and be retrieved. However, using VTOL technology, the ANCILLARY program DARPA is working on will create the next generation of VTOL aircraft, which are lightweight, have a high payload and long endurance during adverse weather conditions, without the need for infractures, such as flight decks and launchers. The programme will also explore new fuel technology, such as electric propulsion systems and fuel cells.

A rendering of a ANCILLARY advanced vertical takeoff and landing aircraft

7 DOORS OPEN
When the F35 engages with STOVL, a door above the LiftFan opens to let air flow through.

9 SYNCHRONIZED
In order for the pilot to take off and land, the LiftFan and engine must operate at the same speed.

6 STAYING STABLE
The roll posts are also used to control aircraft orientation during STOVL and can be operated independently.

4 QUICK ADJUSTMENT
In just two and half seconds, the 3BSM can swivel 90 degrees downwards to redirect thrust.

5 EXTRA SUPPORT
For stability, two roll posts under the wings blast around 10 per cent (around 900 kilograms) of air downward, which has been drawn from engine air flow.

3 REAR FORCE
The majority of thrust comes from the 3-Bearing Swivel Module (3BSM), which funnels more than 8,000 kilogram-force of heated thrust from the plane's turbo engine.

The Bell Boeing V-22 Osprey about to take off

© Getty / DARPA / Lockheed Martin / Illustration by Nicholas Forder

HOW LOUDSPEAKERS MAKE SOUND

This box of electromagnets transforms electrical currents into sound waves

WORDS **SCOTT DUTFIELD**

At its core, a loudspeaker is a transducer, a device that converts one type of energy into another. For loudspeakers, it takes electrical energy and converts it into mechanical wave energy, or soundwaves. The most common type of loudspeaker is known as a moving coil speaker, named after the physically moving copper coil at its centre. The voice coil, as it's known, acts as an electromagnet, which interacts with the magnetic force of a permanent magnet which surrounds it. When an electrical current is passed through the coil, it creates a magnetic field that flows in an opposing direction to the static magnetic field of a permanent magnet. This magnetic interaction either moves the coil forward or backwards depending on the electrical current the speaker is exposed to – the bigger the current, the stronger the attraction and repulsion between the two magnets.

But how does this magnetic dance lead to hearing your favourite song? Attached to the voice coil is a diaphragm called a cone. As the coil is jostled back and forth, the cone follows suit and in the process turns mechanical movement into soundwaves. With each pulse of the cone, the molecules in the air are pushed into each other, creating bunches of high and low pressure. The changing of air pressure creates a wave that vibrates the listener's eardrum and is interpreted as sound. The speed at which the cone moves determines the frequency and volume of soundwaves and ultimately the sound or song that the human ear hears.

Another type of loudspeaker, known as an electrostatic speaker, works by replacing magnets with electrostatic force. Electrostatic speakers use two sheets of negatively charged perforated metal sheets and a positively charged metal-coated diaphragm between them. When an electrical current, created from an audio signal, passes the two metal sheets, the dividing diaphragm becomes more or less attracted to an adjacent sheet and moves. The push and pull action between the sheet causes the diaphragm to vibrate and subsequently produce sound.

Alexander Bell making a telephone call

THE FIRST ELECTRIC LOUDSPEAKER

The first time anyone heard a sound coming from an electric loudspeaker was in 1861 from the telephone of German scientist and inventor Johann Philipp Reis. However, Reis's acoustic creation was far from crystal clear. It wasn't until Scottish inventor Alexander Graham Bell patented his telephone in 1876 that the sound of intelligible voices could be heard from its loudspeaker. Bell's device used a combination of a drum membrane, a piece of cork with a needle attached to it and a battery made of sulphuric acid and a metal contact. When exposed to sound, the membrane vibrated, along with the attached needle, which generated an electric current in the connected battery. The generated current then travelled through a wire to the phone's receiver, which in turn moved another needle and vibrated its attached membrane, sending soundwaves for the listener to hear.

THE LOUDEST SOUND SYSTEM ON EARTH

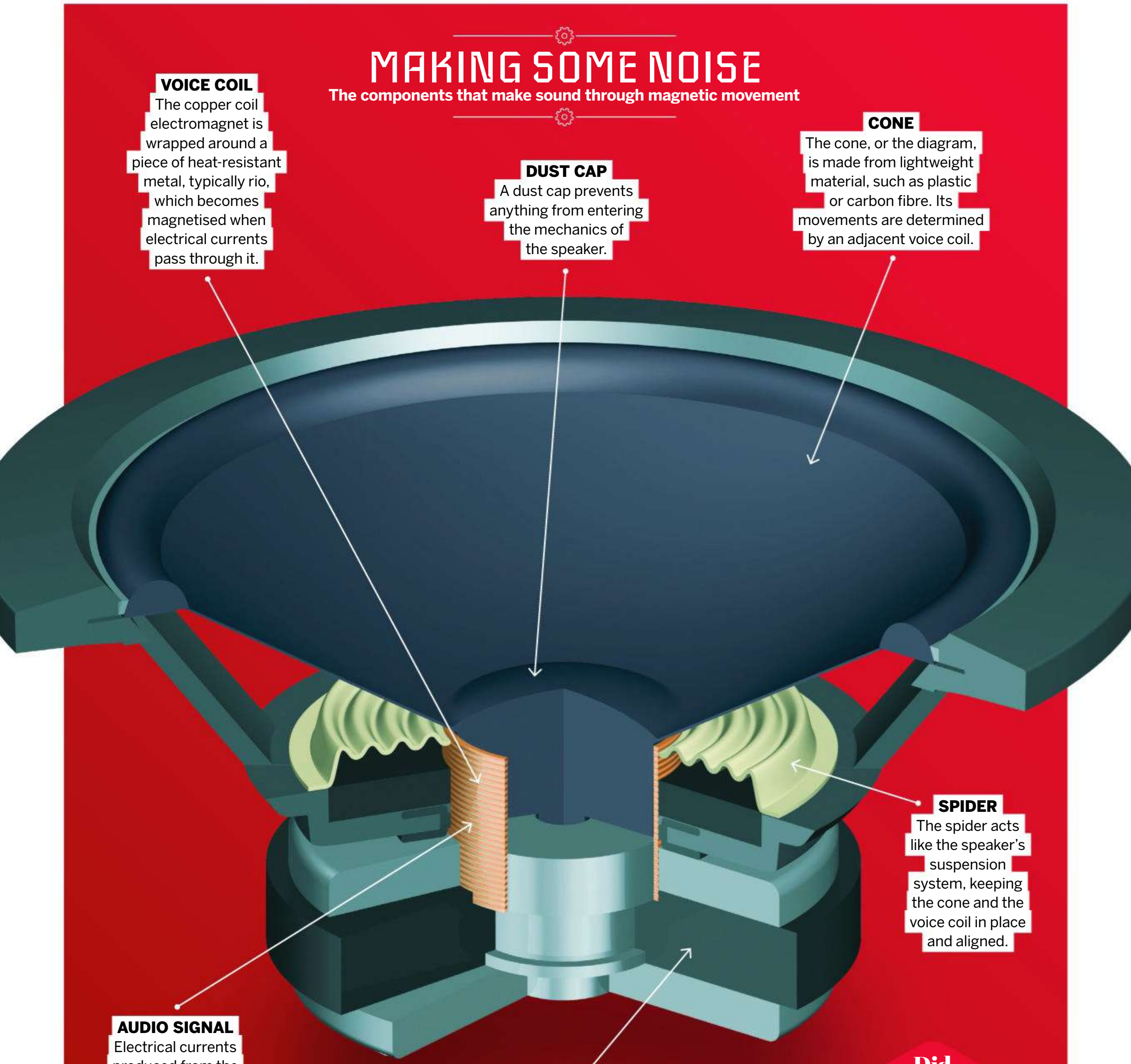
Far from any rock concert or field-bound festival, the largest sound system ever created can be found in a laboratory in the Netherlands. Constructed in 1989, the Large European Acoustic Facility (LEAF) was designed to put space equipment through its acoustic paces. The facility consists of a test chamber around 11 metres wide and more than 16 metres tall, and built from steel-reinforced concrete around half a metre thick. The walls are covered in gigantic sound horns that can blast noise up to 154 decibels, which is the same as standing near multiple jets taking off at the same time. The purpose of LEAF is to measure the noise pressure levels generated by rocket launcher engines and the effect they have on instruments being sent up into space.

The Large European Acoustic Facility (LEAF) hosting the ESA's Rosetta satellite

DID YOU KNOW? Humans can hear soundwaves at frequencies of between 20 and 20,000 Hertz

MAKING SOME NOISE

The components that make sound through magnetic movement



VOICE COIL
The copper coil electromagnet is wrapped around a piece of heat-resistant metal, typically rio, which becomes magnetised when electrical currents pass through it.

DUST CAP
A dust cap prevents anything from entering the mechanics of the speaker.

CONE
The cone, or the diagram, is made from lightweight material, such as plastic or carbon fibre. Its movements are determined by an adjacent voice coil.

SPIDER
The spider acts like the speaker's suspension system, keeping the cone and the voice coil in place and aligned.

AUDIO SIGNAL
Electrical currents produced from the source of the sound, such as a computer, are passed through the wires that form the voice coil.

MAGNET
A permanent ring magnet sits adjacent to the voice coil. When an electric current passes through the voice coil, it generates a magnetic field that interacts with the permanent magnet's field, causing the coil to move.

Did you know?

The speed of sound in air is 331.29 metres per second

© ESA / Getty/ Shutterstock

TECHNOLOGY

BOMB SUITS EXPLAINED

Kevlar is five times stronger than steel by weight

How this bulky armour defends bomb disposal technicians from searing heat, violent explosions and flying fragments

WORDS **AILSA HARVEY**

What do you need to be part of a bomb squad? This team of engineers and technicians is specially trained in the manipulation of live explosive devices. Instead of running from danger, bomb disposal experts get kitted up and face explosives up close so that they can be safely dismantled and disposed of. Bomb technicians need to have good communication and problem-solving skills, the ability to work flawlessly in high-pressure environments and a steady hand.

However, this dangerous job can't expect every mission to be completed successfully and injury-free. In the event of a bomb detonating on the job, bomb squad members are required to wear armour in the form of bomb suits, also known as Explosive Ordnance Disposal (EOD) suits.

In the UK, bomb disposal is carried out by the British Army, Royal Navy and the RAF in former or current war zones and terrorist sites. In mass bombing events, such as those in World War I and II, a small percentage of dropped bombs remain undetonated today. During World War II, bombs dropped from aircraft became bigger and more sophisticated, so advanced training was needed for specialist groups within the British army. Today's bomb squads dispose of grenades, improvised explosive devices, nuclear devices and more.

Did you know?

Nomex takes twice as long to catch fire as cotton

Bomb technicians control communication systems on a device on their wrist

DIGITAL ARMOUR

Most bomb suits are designed so that the wearer can communicate with a base camp and receive guidance. This means that many suits are equipped with a communications device, such as a radio on the shoulder of the suit. This connects to the helmet so that the wearer can speak into the microphone and hear responses through the inbuilt speakers. A video camera is also installed near the technician's head to allow those providing instructions to see the bomb from the technician's perspective.

Modern bomb suits have a cooling system installed into the back of the suit. This creates air circulation around the body and removes hot air from the suit. Wearing this attire for prolonged periods can be intense and temperatures inside this substantial suit can soar. Cooling devices keep the wearer at a comfortable temperature, which is proven to reduce stress in an already mentally demanding situation. Some bomb suits are smart, presenting biometric data such as breathing rate, body temperature and heart rate. This can be closely tracked by observers to ensure that conditions are safe for the wearer to calmly complete a mission.

DID YOU KNOW? The helmet of a bomb suit alone weighs around seven kilograms

HEAVILY ARMOURED

What is a bomb disposal suit made of?

1 HELMET
The helmet protects the head from flying bomb fragments travelling at nearly 700 metres per second.

2 COLLAR
The collar overlaps the helmet to prevent the neck from being exposed. The wide neckpiece is there to prevent a blast from breaking the neck.

3 QUICK RELEASE STRAP
Pulling this strap quickly removes the suit so that injured technicians can be assisted and transported.

4 CHEST PLATE
This steel plate protects the wearer from the force of a bomb's blast.

10 OPTIONAL GLOVES
Bomb suit gloves aren't always worn because dismantling a bomb requires precision and dexterity.

6 KNEE PADS
Knee pads help protect the knees from the weight of the suit when the technician is kneeling next to a bomb.

7 OVERSHOES
A waterproof lining extends from the feet to the knees of the overshoes. These fit over the person's regular footwear.

8 SHIELDING MATERIAL
The suit has a Kevlar layer, which is a strong synthetic fibre, and a flame-resistant outer layer called Nomex.

9 HEAVY GARMENT
The suit weighs over 30 kilograms, so wearers need to be tested to make sure they can handle the load.

5 MODULAR PLATES
Extra groin and breast plates can be attached as modular systems in pouches on the suit.

5 INJURY TYPES CAUSED BY EXPLODING BOMBS

1 BLAST LUNG
Shockwaves from the explosion can cause bleeding into the lungs. Ballistic panels in the suit absorb the strong shockwaves to prevent this injury.

2 CONCUSSION
Blast waves from bombs can cause concussion in people nearby, even if there isn't a direct injury to the head. Helmets are shockwave and shrapnel resistant.

3 FRACTURE
When in close proximity to a bomb blast, people may be thrown into the air, increasing the chances of broken bones. The suit's material absorbs much of the landing impact.

4 BURNS
Thermal radiation released by explosions causes severe skin burns to unprotected bodies. The suit's exterior fibres swell when exposed to flames, forming a thicker barrier.

5 BLUNT INJURY
Flying debris launched from a bomb can pierce the skin and organs. The fibres of the suit are woven so tightly that shrapnel is unable to separate them and penetrate the body.

"Today's bomb squads dispose of grenades, IEDs, nuclear devices and more."

© Alamy / Shutterstock

INSIDE A FIRE EXTINGUISHER

These portable devices eliminate small fires before they rage out of control

WORDS **ALISA HARVEY**

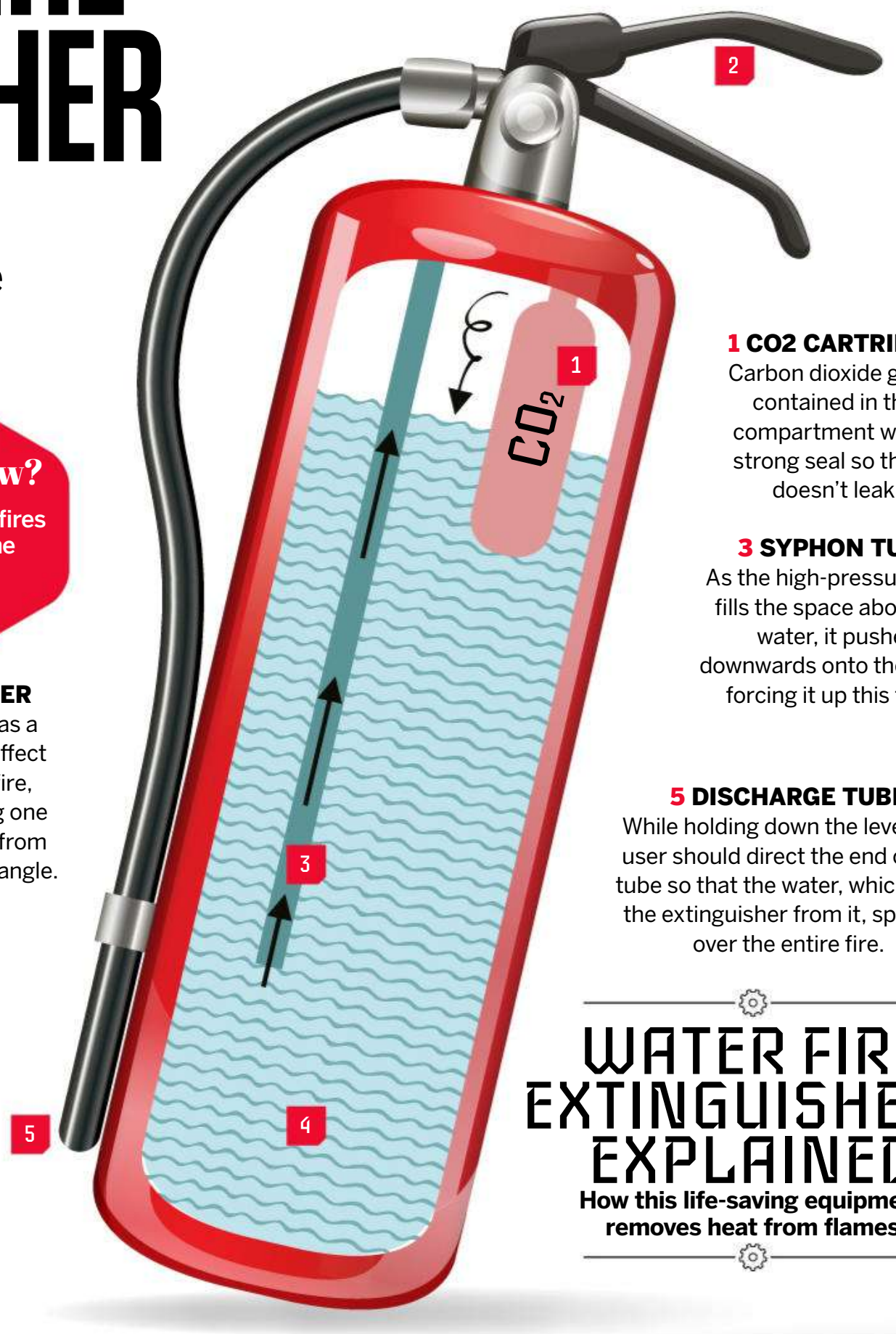
You might have seen the large cylinders secured to the walls of your school, distributed in the workplace or installed in your own home. These are fire extinguishers, pressurised devices designed to rapidly release water, gas or solid powder. In many countries, it is a legal requirement for private and public organisations to have them distributed around their buildings – and for good reason. When activated by squeezing the handle, fire extinguishers can put out around 80 per cent of all fires. When they aren't installed within a short distance of any location, fires are more likely to continue to burn for longer, destroying buildings and in the worst instances taking people's lives.

Simply owning a fire extinguisher is not enough to maximise your protection against a blaze. Most extinguishers last for around 10 to 12 years before they need to be replaced. Over time, the internal pressure of these devices decreases, reducing the speed at which their contents are released. The nozzle can also become clogged or broken if containers are not stored safely and maintained properly.

Did you know?

Most house fires start in the kitchen

2 CO2 DISCHARGE
When the user presses down on the lever at the top of the fire extinguisher, a pin pierces the gas cartridge, releasing CO2.



1 CO2 CARTRIDGE
Carbon dioxide gas is contained in this compartment with a strong seal so that it doesn't leak.

3 SYPHON TUBE
As the high-pressure CO2 fills the space above the water, it pushes downwards onto the water, forcing it up this tube.

4 WATER
Water has a cooling effect on the fire, removing one element from the fire triangle.

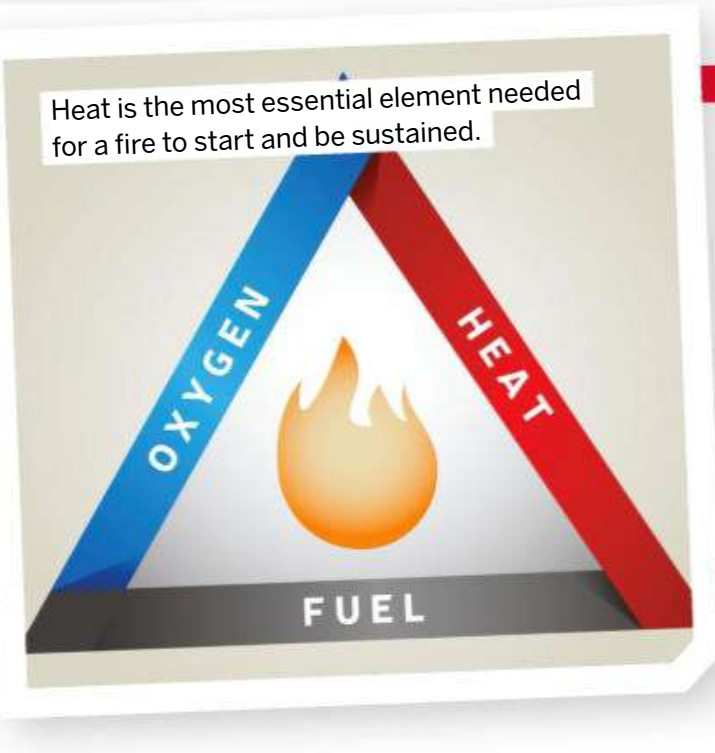
5 DISCHARGE TUBE
While holding down the lever, the user should direct the end of this tube so that the water, which exits the extinguisher from it, spreads over the entire fire.

WATER FIRE EXTINGUISHERS EXPLAINED

How this life-saving equipment removes heat from flames

BREAKING THE FIRE TRIANGLE

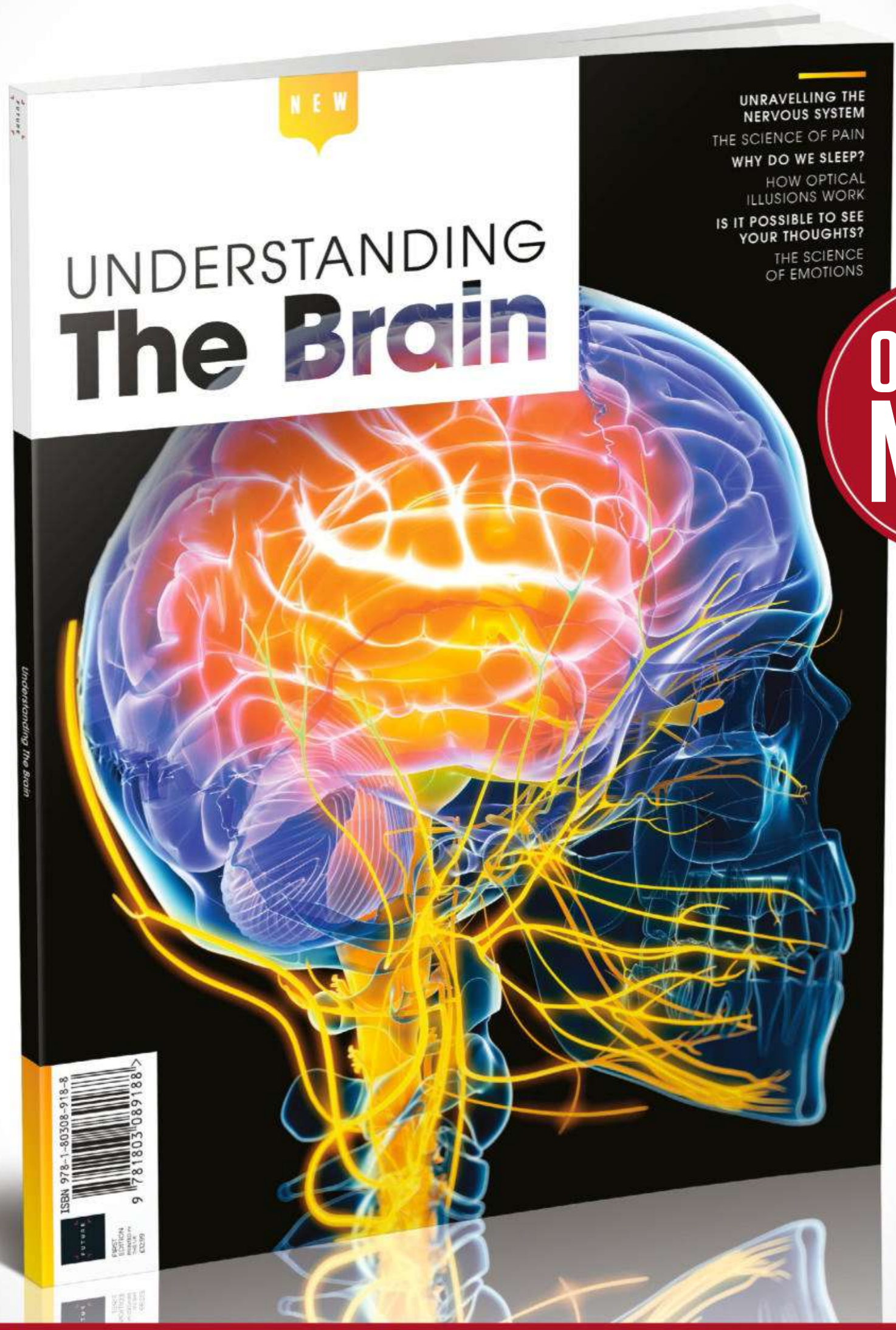
Oxygen, fuel and heat are the three elements that a fire relies on to ignite and continue burning. If you successfully remove just one of these elements with a fire extinguisher, the fire will be extinguished. Fire extinguishers are engineered to remove fires by tackling one side of the triangle. Water fire extinguishers spray water out of the discharge tube to lower the temperature of fire, while CO2 extinguishers release heavy carbon dioxide gas. Because carbon dioxide is heavier than oxygen, it can easily smother the flames and push out the lighter oxygen. The third part of the triangle – fuel – is removed by a dry powder extinguisher. From this, sodium bicarbonate powder is sprayed. The powder sticks to the fuel's surface, fully coating it to prevent its contact with the flames.



©Getty / Alamy

DISCOVER THE FASCINATING BIOLOGY OF YOUR BRAIN

This special edition from the makers of How It Works takes a deep dive into the most complex structure in the known universe: the human brain. Learn about its anatomy and function, as well as our emotions, dreams, and more.



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SCUBA DIVING SCIENCE

Deep dive into the physics, physiology and equipment of this popular sport

WORDS **AILSA HARVEY**

The air tank that provides oxygen to divers is called SCUBA, which is an acronym for self-contained underwater breathing apparatus. Despite this sophisticated diving equipment, which keeps the body stable and oxygenated while underwater, spending significant periods below the surface can still be dangerous. For safe scuba diving, there are important procedures taught during training and diving.

Firstly, divers should never hold their breath. As Boyle's law about the state of gases explains, any gas in a diver's lungs will expand during ascents and contract when descending. If you hold your breath and the gas begins to expand, it will become trapped and can cause severe damage to the lungs. Dives should be planned well, with maximum depths and time decided beforehand. Without these guidelines, divers are more likely to venture further and deeper underwater, potentially encountering difficulties when ascending. Beginners should always dive with a second diver. This person is called a dive buddy and they are responsible for checking your equipment – and you theirs. If either diver faces difficulties in the water, the other is on hand to step in and assist them.

The first scuba was invented by a French navy officer called Yves le Prier in 1926

A buoyancy control device (BCD), worn as an outer layer

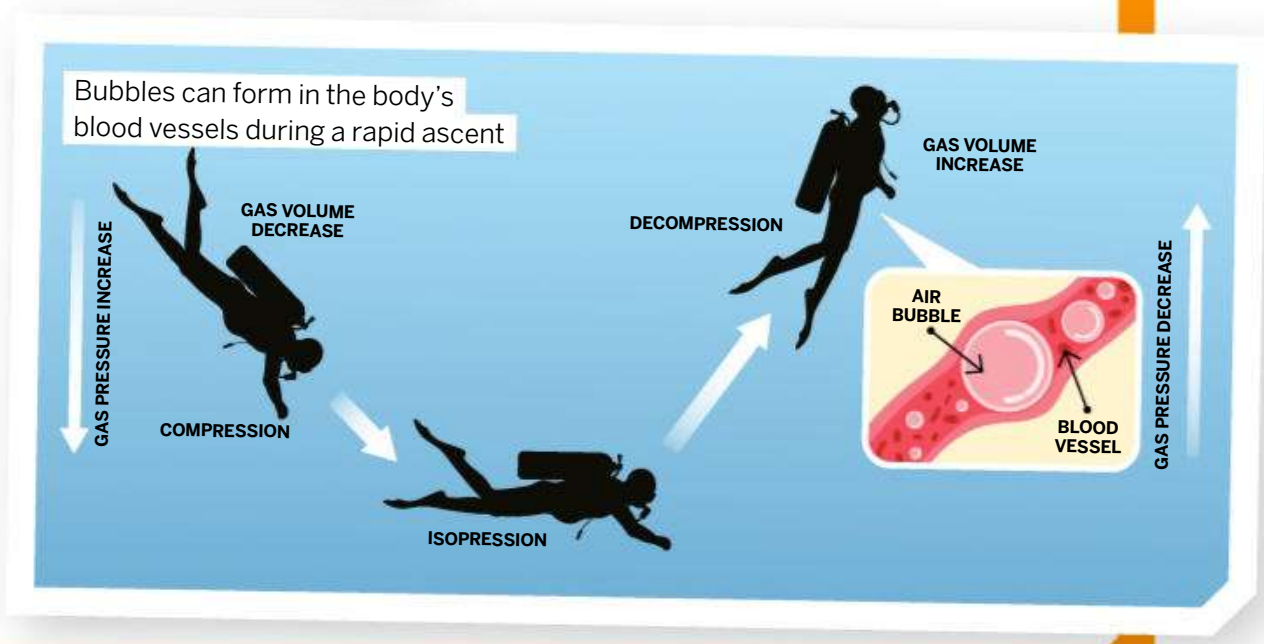
WHAT TO WEAR

The heaviest item that a scuba diver carries is the oxygen tank. But considering the tank allows divers to breathe comfortably for around one hour, it's relatively compact. This is because the air inside it is stored at a high pressure, compressed to pack in as much gas as possible into a small volume. By monitoring how much the tank's pressure has dropped, divers keep track of how much air they have remaining by viewing their pressure gauge. This gauge is at the front of the diving suit to help inform the diver about when to return to the surface.

Buoyancy is also a major factor. If you've ever tried to stay still in the water with no equipment, you will find that your body will struggle to remain submerged in one spot. This is because muscle is dense and usually sinks, while fatter parts of the body are less dense than water, and float. An inflatable jacket known as a buoyancy control device (BCD) helps divers float on the surface or at a certain level underwater.

WHAT ARE THE BENDS?

Your body works differently in deep water. As a diver descends, hydrostatic pressure increases. This pressure is the force that is exerted on an object by a liquid (the sea). For every ten metres, the pressure increases by one atmosphere. As this increases, so does the volume of gas that enters the body's tissues. Around 80 per cent of the air we breathe is nitrogen, which is trapped in the body at depth and can become a problem when the diver resurfaces. Decompression sickness can happen when a diver ascends too quickly for nitrogen to leave the tissues and exit via the lungs. Instead, it bubbles throughout the body in a painful phenomenon known as the bends. To treat this, divers use hyperbaric chambers to breathe oxygen under high pressure. This forces the nitrogen to return to a liquid form and exit the body safely.

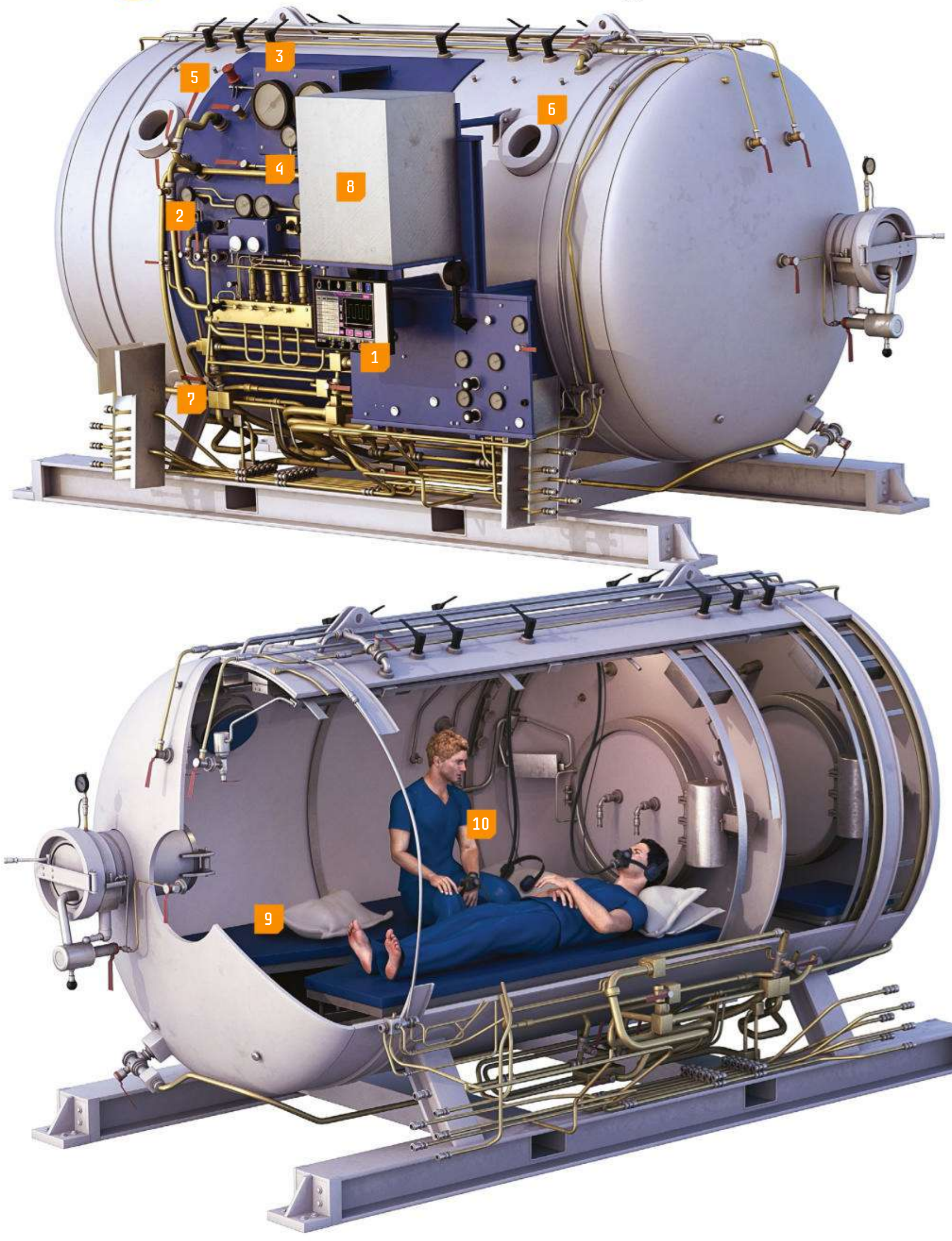


Did you know?

About 80 per cent of the ocean is unexplored

INSIDE A HYPERBARIC CHAMBER

The dreaded bends can be deadly – this is how to treat it



1 CONTROL PANEL
An operator is always present to monitor the divers inside.

2 REGULATOR
Usually set between 300 and 450 psi, this controls the pressure of the air entering the chamber.

3 LOCKS
Chambers usually have two compartments (an inner and outer section) so that the pressures can be adjusted separately, to maintain the central chamber's pressure.

4 DEPTH GAUGE
The pressure of the chamber is displayed here.

5 LEVERS
The operator pulls levers to manage the speed at which oxygen enters the decompression chamber.

6 PORTHOLES
These small glass windows enable the operator to communicate with the divers inside.

7 EXHAUST VALVE
To depressurise the chamber or create a flow of air to reduce humidity inside, air is released by turning this valve.

8 OXYGEN CONTAINER
100 per cent oxygen is released into the chamber for the divers to breathe. With the high air pressure inside, this increases the body's uptake of oxygen.

9 TREATMENT BEDS
While receiving treatment, divers lie on these beds for two hours.

10 DIVERS
Oxygen is supplied to the divers through a face mask. The surrounding air is not 100 per cent oxygen.

© Getty / Alamy / Shutterstock / Illustration by Nicholas Forder

HOW CPR SAVES LIVES

Repeated chest compressions and electric shock can be enough to kickstart a heart

WORDS **SCOTT DUTFIELD**

CPR requires a person to compress the chest more than 100 times a minute

Cardiopulmonary resuscitation (CPR) is the emergency procedure used to replicate the heart's regular rhythm and ultimately save someone's life. In the event that a person experiences cardiac arrest, they quickly fall unconscious due to the lack of oxygenating blood reaching their brain and lungs. To mimic the heart's natural blood-pumping function, someone trained in CPR can use chest compression to pump blood in and out of the heart manually and pump oxygen-rich blood around the body until emergency medical intervention.

Although they might seem alike, a cardiac arrest is not the same event as a heart attack. When someone experiences a heart attack, the blood supply to the organ is blocked, typically by the buildup of substances such as fat or cholesterol. The heart cannot receive oxygen and begins to fail. A cardiac arrest, on the other hand, occurs when the heart stops pumping blood to the entire body, the patient stops breathing and falls unconscious. While both require urgent medical attention, those suffering a heart attack often remain conscious until they experience a cardiac arrest.

Did you know?

9 out of 10 people experience cardiac arrest outside of a hospital

CPR chest compressions can be accompanied by rescue breaths, also known as mouth-to-mouth. However, they are not mandatory to complete CPR, and are typically used by people with first aid training. After 30 chest pumps, you would tilt a person's head gently the neck, seal your mouth over the unconscious person, blow for a second, repeat once more, then continue compressions. A rescue breath inflates the lungs with oxygen, as well as carbon dioxide, to increase the oxygenated blood supply to the body's vital organs.

In the event that the person enters cardiac arrest in the vicinity of an automated external defibrillator (AED), anyone can use them to try and jump-start someone's heart. Much like the defibrillators seen in a TV hospital drama, AEDs send electric pulses through sticky patches to restore the electrical rhythm of the heart. However, they are designed to be used by an untrained hand and therefore come with built-in sensors to detect the heart's rhythm, or lack thereof, and automatically deliver a shock.

An automated external defibrillator (AED) being used on a practise dummy

"Although they mightseem alike, a cardiacarrest is not the sameevent as a heart attack"

THE EVOLUTION OF CPR

Early ages (~1,000 CE)

Whips and stinging nettles were used to strike those experiencing cardiac arrest in the hopes of shocking them back to responsiveness.

1530

Swiss physician Paracelsus uses fireside bellows to force air into an unconscious person's lungs for revival. It's a practice that went on until the early 1800s.

1732

Scottish surgeon William Tossach uses mouth-to-mouth to revive someone. In 1740, the Paris Academy of science recommended the method for resuscitation.

1770

The inversion method was used, typically for drowning victims, requiring the body to be strung up by the feet to remove water from the lungs and add pressure to the chest to assist breathing.

1773

The barrel method was used to simulate respiration by putting a person in a barrel and repeatedly rolling it to apply and release pressure to a person's chest.

DID YOU KNOW? CPR performed outside a hospital has a success rate of less than 12 per cent

THE CPR MACHINE

CPR can be strenuous. Some organisations suggest a minimum of 20 minutes before ceasing resuscitation. However, other studies have shown that maintaining compressions for 30 to 45 minutes could lead to a 'return of spontaneous circulation'. Spending this much time manually pumping a chest can be tiring, therefore some automated alternatives, such as the LUCAS chest compression system, have been created. LUCAS uses an integrated mechanical suction cup and blackboard. It's also equipped with sensors to measure the resistance of the body and adjust the force needed to reach the perfect compression depth.

The LUCAS 3 chest compression system and carry case

FIRST AID

Here are some of the steps a first aider takes to resuscitate an unconscious, unresponsive adult who is not breathing

1 CALL FOR HELP
A first-aider may immediately call the emergency services (on loud speaker) while they begin CPR. If there are other people around then they should locate the nearest defibrillator.

2 HAND PLACEMENT
While on their knees, the heel of one hand is placed in the centre of the chest and the palm of the other hand is placed on top of the other, interlocking the fingers.

3 COMPRESSION
With a shoulder positioned directly above the hands, the arms are locked straight while pressing straight down by five to six centimetres on the chest.

4 RELEASE
Keeping the hands on the chest, the compression is released and the chest allowed to return to its original position.

5 REPEAT
Compressions are repeated at a rate of 100 to 120 times a minute, which is also the beat of the song 'Stayin' Alive' by the Bee Gees.

6 DEFIBRILLATOR
If a defibrillator is available then the instructions should be followed while CPR is continued.

1812
Horses were used to to mimic the pressure changes of the chest of an unconscious person by draping them over a horse's back while it trotted along.

1891
Dr Friedrich Maass is renowned for being the first person to restart the hearts of two patients by using manual chest compressions.

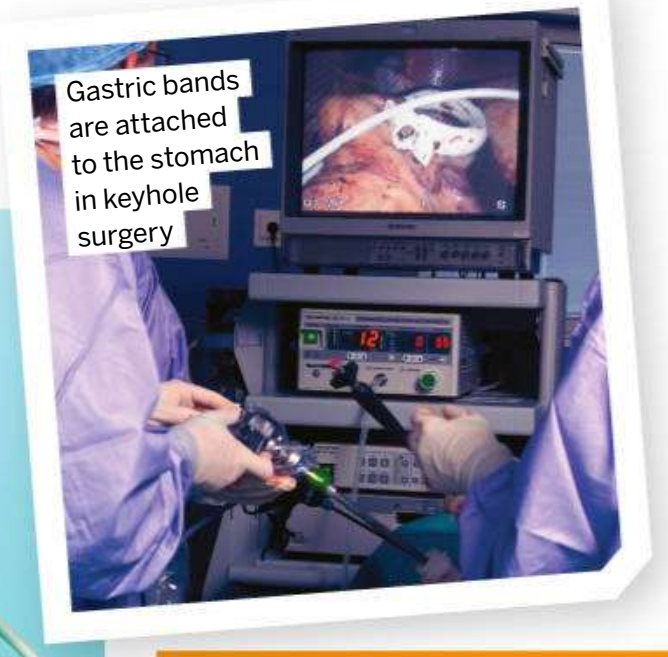
1903
Hungarian physician Rudolf Eisenmenger published a paper describing a "device for artificial respiration", which used an electrical suction pump to compress the chest.

1957
The first external defibrillator is created by a team of scientists at John Hopkins Hospital, called the Hopkins Closed Chest Defibrillator

1960
The same team of Hopkins scientists that invented the external defibrillator combined mouth-to-mouth and chest compression to develop the living-saving method known as CPR.

© Getty / LUCAS / Illustrations by Ed Crook

HOW DO GASTRIC BANDS WORK?


Gastric bands are attached to the stomach in keyhole surgery

In this weight-loss procedure, surgeons tighten the stomach with a ring

WORDS **AILSA HARVEY**

There are more than a billion people in the world who are obese. To be classed as obese, a person has to have a body mass index (BMI) of 30 or higher. This is a measurement calculated using height and weight, and isn't always applicable to athletes or people with large muscle mass. Obesity increases the chances of developing cancer, diabetes, heart disease and other deadly diseases, and this is the main reason that many people seek a quick solution to lower their BMI.

There are many diet, exercise and other lifestyle changes that can be made to lose weight naturally, but these require commitment and consistency over a long period of time, and aren't always practicable.

If losing weight by making lifestyle changes proves unsuccessful, some people opt for weight-loss surgery instead. Gastric banding is one form of weight-loss surgery, and works by physically reducing how much a person can eat by clasping the top of the stomach. It means that food and drink fill up the stomach more quickly. For this reason, people who undergo gastric band surgery need to eat slowly to learn the stomach's new limits and prevent it from overflowing.

Did you know?

In six months, gastric band patients lose up to 50 per cent of weight

WHAT ARE THE RISKS?

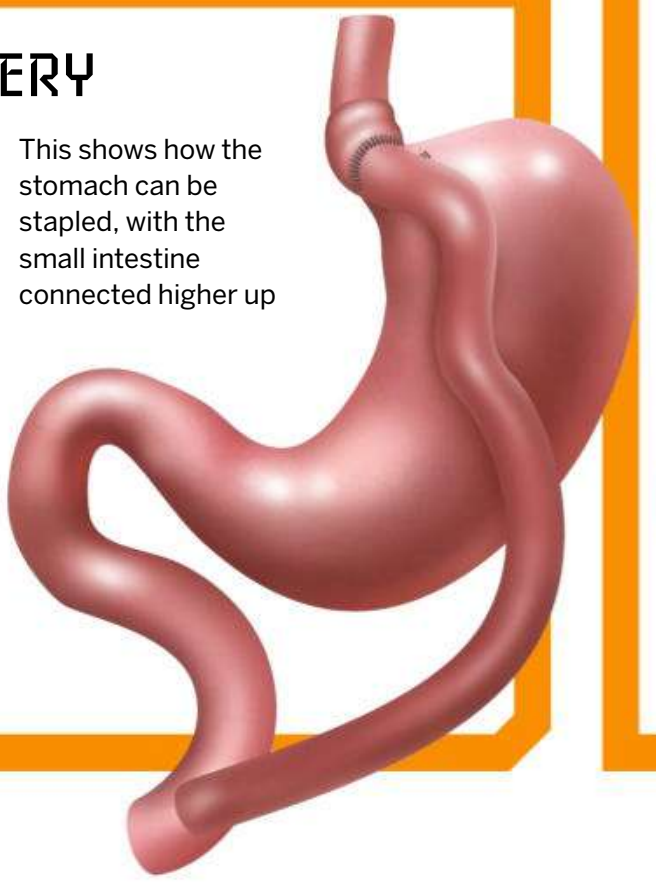
Gastric bands can help people who have reached an unhealthy weight to lower it and improve their health. However, these devices make the body work in an unnatural way and are only recommended by doctors when patients have a high body mass index of at least 40. They must also have tried other natural weight-loss options, like exercise and dieting.

In some cases, the gastric band can move over time. If the band moves too far up or down the stomach, patients can suffer from heartburn, feeling nauseous and vomiting. Between 15 and 60 per cent of people who have had a gastric band fitted need to have a follow-up operation to put the band back in place. Another risk factor is the small chance of the gut being blocked. A gastric band can reduce the blood flow to the stomach and small intestine, making them narrower and increasing the chance of blockages. Lastly, due to the limited absorption of nutrients into the body that comes from restricting part of the stomach, gastric band wearers should put in the effort to follow a balanced, nutrient-rich diet. Without including all the nutrients in their limited consumption, patients risk suffering from malnutrition.

Doctors may suggest a gastric band if your BMI is between 35 and 40 but you also have a serious condition that the procedure could help with

TYPES OF WEIGHT-LOSS SURGERY

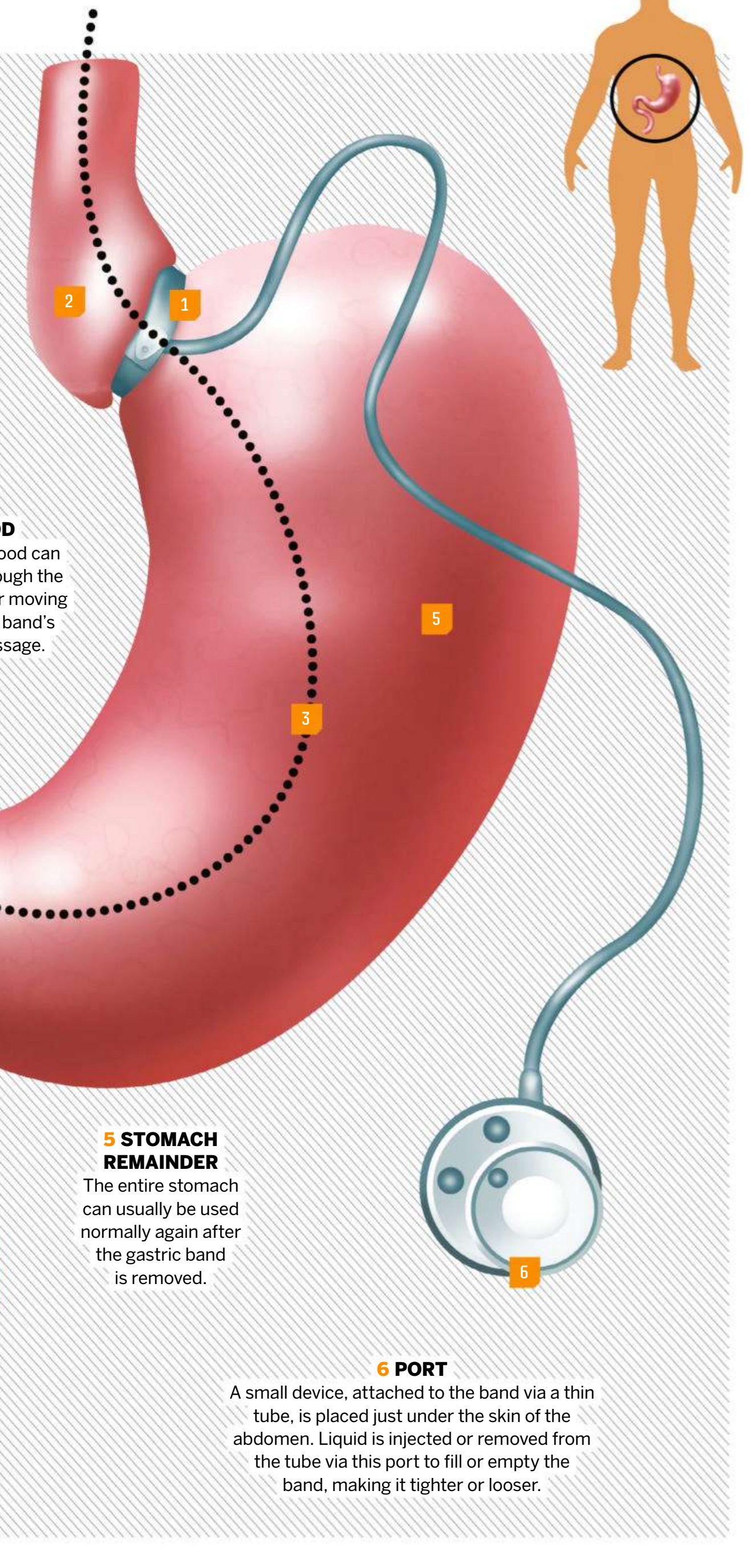
Gastric banding isn't the only way in which obese patients can reduce their weight rapidly. Another similar surgery is the gastric bypass, which skips the stomach stage of digestion completely. This process, called malabsorption, involves a surgeon cutting or stapling the top of the stomach to prevent food from entering. Instead, a small pouch is made at the top of the stomach. The surgeon then connects the small intestine directly to this pouch. The gastric bypass method sees results very quickly, but is more difficult to reverse. The third weight-loss surgery is a sleeve gastrectomy. For this procedure, around 80 per cent of the stomach is stapled together. This stops one side of the stomach from taking part in digestion and is a non-reversible procedure.


This shows how the stomach can be stapled, with the small intestine connected higher up

DID YOU KNOW? 650 million adults, 340 million adolescents and 39 million children are obese worldwide

A SMALLER STOMACH

What does the stomach look like after gastric band surgery?



1 GASTRIC BAND
A silicone rubber band is tightened around the top of the stomach.

2 STOMACH POUCH
The top section of the stomach fills up quickly when eating, creating the sensation of feeling full after a smaller portion of food.

3 FOOD
Consumed food can still pass through the stomach after moving through the band's narrow passage.

4 DIGESTIVE JUICES
The lower section of the stomach still secretes digestive juices, helping break down the food after it passes through the band.

5 STOMACH REMAINDER
The entire stomach can usually be used normally again after the gastric band is removed.

6 PORT
A small device, attached to the band via a thin tube, is placed just under the skin of the abdomen. Liquid is injected or removed from the tube via this port to fill or empty the band, making it tighter or looser.

© Alamy / Getty

Did you know?

Less than one per cent of your tears is salt

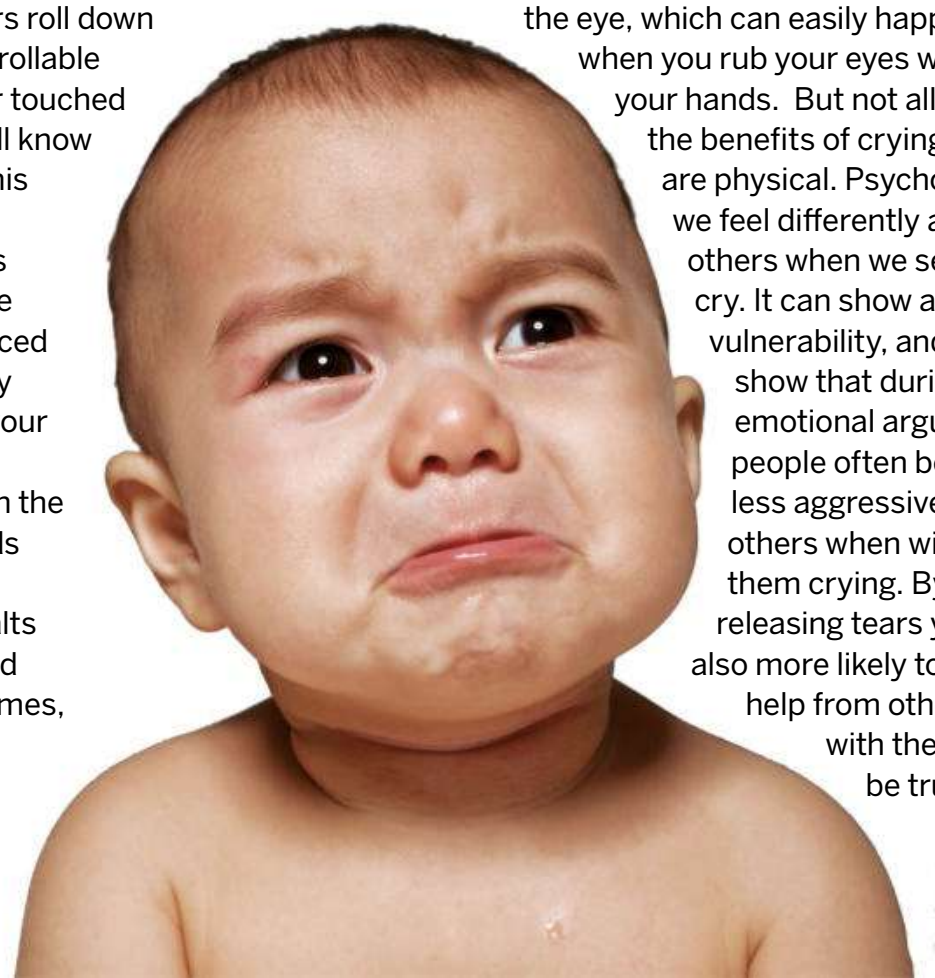
WHAT ARE TEARS MADE OF?

The psychology behind crying and why our eyes water

WORDS **AILSA HARVEY**

Tears are a clear liquid that fills your eyes when you experience significant pain, overwhelming emotion or the invasion of an irritant, but not all tears roll down your cheeks in uncontrollable streams. If you've ever touched your own eyeball, you'll know that it's always wet. This is because tears are produced by your eyes constantly. Usually, the volume of tears produced is low enough that they don't overflow out of your eyes. Instead they're drained by tiny holes in the upper and lower eyelids called tear ducts.

Tears contain the salts potassium chloride and sodium chloride, enzymes, lipids and essential minerals such as calcium and magnesium. Lysozyme is one of the most abundant enzymes in tears, as the first line of defence against bacteria. This protein works to kill any bacteria that enters the eye, which can easily happen when you rub your eyes with your hands. But not all of the benefits of crying are physical. Psychologically, we feel differently about others when we see them cry. It can show a person's vulnerability, and studies show that during emotional arguments, people often become less aggressive towards others when witnessing them crying. By releasing tears you're also more likely to receive help from others, bond with them and be trusted.



WHY WE CRY WITH HAPPINESS

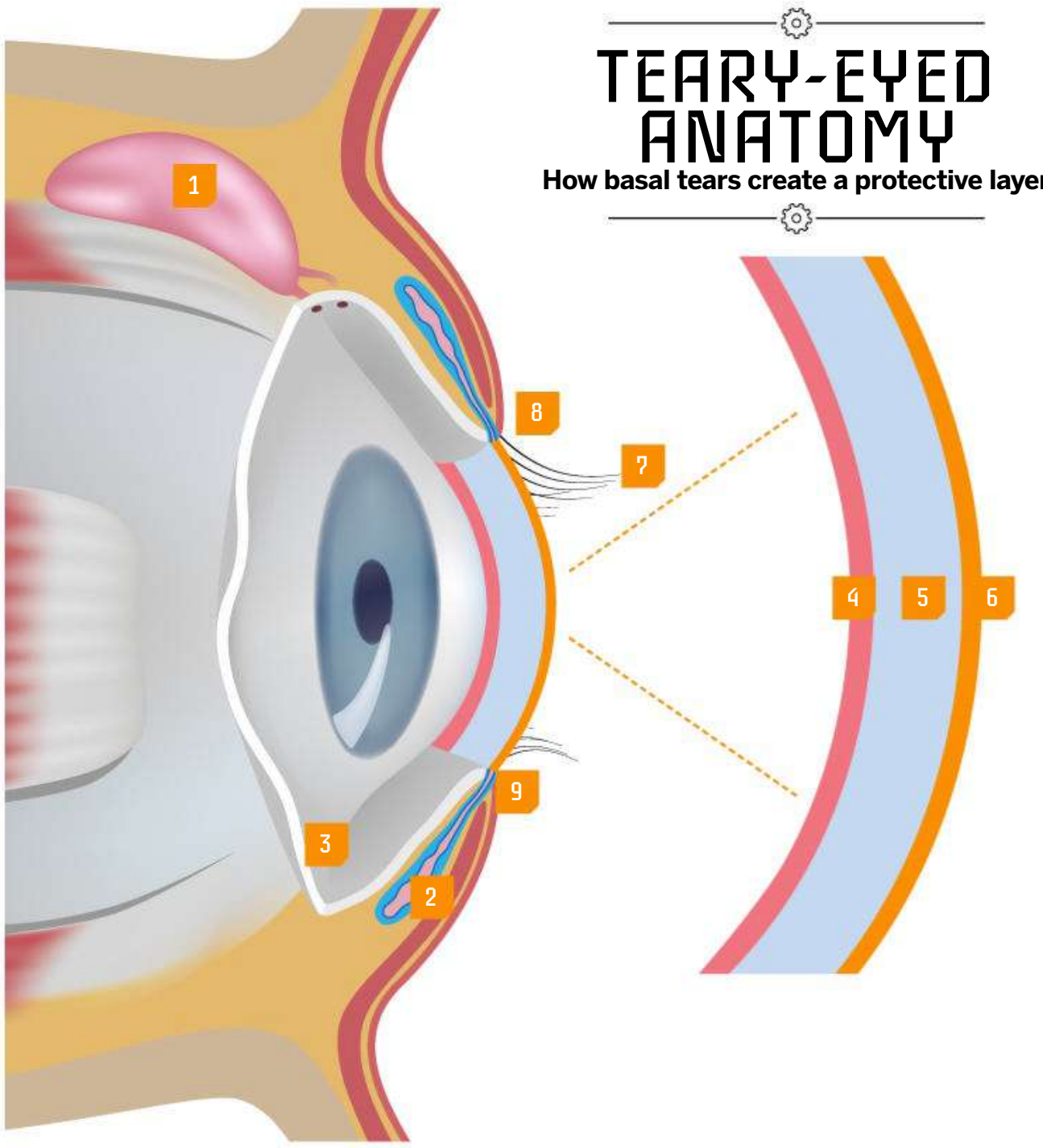
Crying is a release of emotion, but this emotion doesn't always have to be sadness. Have you ever been reunited with a close friend and burst into tears as soon as they arrived? Or perhaps you've been to a wedding and noticed many of the guests wiping away their tears. Although you know when you are happy and sad, the brain can become overwhelmed by influxes of such strong emotions. Both positive and negative emotions are dealt with in similar ways by releasing tears. The amygdala is the part of the brain that processes emotional and behavioural responses. Just before you cry with happiness, the amygdala sends a signal to the glands in the eyes to make them produce more tears. When these tears are released from the eyes, the hormone oxytocin is also released in the body, working to calm the body by instigating physical changes such as reducing blood pressure. In the same way that sad crying relieves the negative emotions felt, happy crying stops the brain being overwhelmed with opposing changes in your mental state.

Happy tears are sweeter tasting because they're less acidic

DID YOU KNOW? Tears are made up of over 1,500 different proteins

TEARY-EYED ANATOMY

How basal tears create a protective layer



1 LACRIMAL GLAND
One of these glands is located above each eye. Here the bulk of tears are continuously released onto the outside of the eyeball.

2 MEIBOMIAN GLAND
Around 30 of these glands line the lower eyelid. These and the 40 on the upper eyelid release oil into tears.

3 CONJUNCTIVAL GOBLET CELLS
These cells produce a protein called mucin, which lubricates the eye and prevents the eyelids from sticking to the surface of the eyeball.

4 MUCOUS LAYER
This inner layer contains a protein called mucin, which is sticky and keeps the tear film attached to the eyeball.

5 AQUEOUS LAYER
The biggest portion of the tear film is water. This layer is 98.2 per cent water and 1.8 per cent solids to hydrate and nourish the eye.

6 LIPID LAYER
When excreted from the meibomian glands, the oily layer prevents the water in the tears from evaporating and makes the eyeball's surface smooth.

7 EYELASHES
The small hairs that stick out from your eyelids reduce the movement of air around the eyes so that tears don't evaporate quickly.

8 EVEN SPREAD
Each time you blink, the three-layered tear film is spread evenly across the eyeball's surface by the eyelids.

9 TEAR DUCTS
These passages carry tears from the eye into the nose. Here the old tear film can exit the body by evaporation or re-enter the body.

TYPES OF TEAR

The act of crying can have negative connotations, but not all crying is the same. Some tears are produced during highly stressful and emotional events, while others are formed after a single cut into an onion. There are three types of tears, differentiated by their triggers and impact on the body: basal, emotional and reflex tears. Each type also varies in its composition. Basal tears are always present on your eyeballs. They are made up of three layers, serving as a protective coating for delivering nutrients to the eyes. Without these tears, your eyeballs would dry out.

While basal tears work to keep small amounts of physical debris out of the eyes, emotional tears relieve stress and help to stabilise mental health. Stress chemicals have been detected in emotional tears, meaning that the act of crying can literally flush overwhelming feelings away. The third type is reflex tears. These are mostly made of water, which is released in higher volumes when an irritant such as a small insect – or the enzymes and acid released by onions when they're cut – makes contact with the eyeball. More antibodies, which are defence proteins of the immune system, are released in these tears to fight any harmful cells that might enter the eye.

Onions release sulphur when cut, which forms the irritant sulphuric acid when it makes contact with the water on your eyes, causing more tears to be produced

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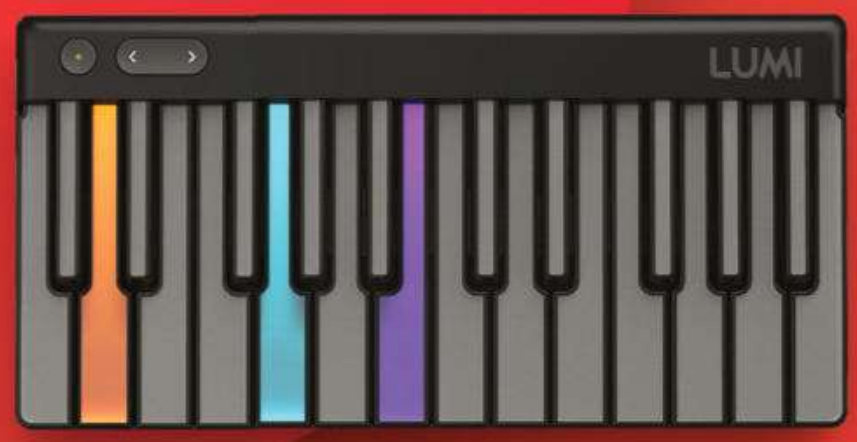

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For your chance to win, answer the following question:

What's the name of the region of space where most of the asteroids in the Solar System are located?

A: ASTEROID RIBBON B: ASTEROID HOOP C: ASTEROID BELT

Enter online at **howitworksdaily.com** and one lucky entrant will win!

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BRAINDUMP

Amazing answers to your curious questions

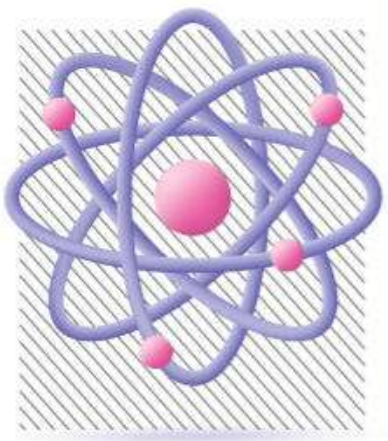
Why do silverback gorillas have silver backs?

Pete Hodgson

Male gorillas develop a saddle-shaped area of silvery hair on their backs when they reach sexual maturity. Silverback gorillas' silvery fur is for display, and communicates to other gorillas that they're adult males. Many other species have equivalent markers performing this function – for example, facial hair in male humans or manes in male lions. A typical gorilla family consists of a dominant silverback male, sometimes other silverbacks that support the dominant male, younger blackback males, adult females, juveniles and infants. The dominant silverback plays an important role in keeping the group together, as well as protecting it.

Did you know?

Silverbacks live for about 35 to 40 years



WHY DO ATOMS HAVE ELECTRONS?

Roy Munneke

Electrons are one of the fundamental particles in atoms. They neutralise the charge of an atom, their negative charge balancing out the positively charged protons – that's why there's always an equal number of electrons and protons in an atom. Electrons are also responsible for atom bonding. Atoms always want a full outer shell of electrons, and to this end they gain, lose or share electrons with other atoms, often forming new materials in the process. As electrons are the part involved in bonding, the configuration of electrons in an atom is what gives an element its specific chemical and physical properties.

DID SIR WALTER RALEIGH INTRODUCE POTATOES AND TOBACCO TO EUROPE?

Kamil Castillo

This myth, along with many others associated with the explorer and privateer Sir Walter Raleigh, is false. While it's true that on returning to England from the New World in 1586 Raleigh did indeed present both potatoes and tobacco to Queen Elizabeth I as gifts, he was not the first person to bring either product to Europe. According to records, potatoes were already being grown and distributed in Italy from 1585 onwards, an entire year before his return.

While Raleigh has gone down in history as the man who introduced one of the most addictive habits – smoking tobacco – he can't take any credit at all, with Frenchman Jean Nicot introducing it to France in 1560. As such, Raleigh did not introduce the potato and tobacco at all; instead they slowly spread through Europe as merchants carried and exchanged the products on burgeoning 16th-century trade routes.

IS IT TRUE THAT THE GREEK HERO ACHILLES WAS KILLED BY AN ARROW TO HIS HEEL?

Frank West

This is 'true' in the same sense that Superman can only be stopped by Kryptonite. Achilles was the greatest of all the Greek heroes who besieged the city of Troy in Homer's epic poem *The Iliad*. It is said that Achilles' mother dipped him in the River Styx – the river of the ancient Greek underworld – to make him impervious to wounds. Achilles' heel did not go into the water because that was where she was holding him, and so it was the only place where he was vulnerable. In Greek mythology, the Trojan prince Paris shot Achilles in the heel with an arrow and killed him. A person's 'Achilles' heel' has become proverbial for a critical weakness. The city of Troy was later captured by the Greeks and its inhabitants were killed or enslaved.

WHY IS THE MOON SOMETIMES VISIBLE DURING THE DAY?

Maddy Beane

This all depends on where the Moon is in its current lunar cycle. At full Moon it is exactly opposite the Sun, giving us a very bright Moon in the night sky but nothing during the day. As it gets closer to new Moon phase, the Moon is moving closer to the Sun. This makes it less bright at night but more visible during the day. The only time the Moon is hardly visible to us is when it's directly between us and the Sun and none of the Sun's light is reflecting off the Moon towards us. If you watch the Moon every night for a month you will be able to see the different phases and its varying positions in the night sky.

What's the difference between a wasp and a hornet?

Debbie Jackson

There are many different groups of Hymenoptera – the insect order that also includes ants and bees – that are called wasps, including an awful lot of very obscure parasitoid wasps. However, when most people think of wasps they think of the black-and-yellow variety that build paper nests and live in colonies. These common wasps are classified in two very closely related genera: *Dolichovespula* and *Vespula* – the common wasp is *Vespula vulgaris*, for instance. Hornets, with one British species and several in Asia, are the closest relatives to these wasps, but separated from the ancestors of *Dolichovespula* and *Vespula* long enough ago that we place them in a separate genus: *Vespa*. As well as being substantially bigger than a wasp, the hornet can be separated from wasps in Britain by its 'fat' head: looking from above, the head expands behind the eyes, whereas in *Vespula* and *Dolichovespula* the head narrows behind the eyes.

© Alamy / Getty

BRAINDUMP

HOW DO PALAEONTOLOGISTS DETERMINE WHICH PERIOD A DINOSAUR BELONGED TO?

Brian Harding

As dinosaurs and other fossils don't come with a date stamped on them, geologists have to use evidence from the rocks in which they are found to ascertain which geological period they belong to. The absolute ages of rocks in millions of years can be estimated accurately using the decay of radioactive isotopes. However, relative ages are normally determined using particular fossils, such as ammonites, that lived only for short lengths of geological time. In the case of dinosaurs, tiny plant spores and pollen usually allow them to be placed into the correct geological period.

Did you know?
Nyasasaurus parringtoni is the oldest dinosaur

Is it true that Mary, Queen of Scots, ordered for Queen Elizabeth I to be assassinated?

Susie Mack

Mary was certainly accused of sanctioning the attempted assassination of Queen Elizabeth in 1586 – the infamous Babington Plot. This scheme, led by Sir Anthony Babington, planned to kill the Protestant Elizabeth and replace her on the throne with the Catholic Mary. The proof of Mary's involvement with this plot rested on letters between she and the plotters, where she undoubtedly agrees to the plan. However, there has always been a suggestion that this evidence was fabricated by Elizabeth's spymaster, Sir Francis Walsingham. The court clearly believed him, and Mary was executed for treason at Fotheringhay Castle on 8 February 1587. To the end she protested her innocence. As with many events in Scottish history, it depends on who you believe as to whether Mary, Queen of Scots, was a martyr or a conspirator to murder.

IF I FIRE MY LASER PEN INTO THE SKY, HOW FAR WILL THE BEAM TRAVEL?

Adam Vega

It all depends on the power of the laser and how sensitive the device to 'see' it is. Particles in the air block the light photons and slowly spread the light out, eventually making it invisible to the naked eye. To get an idea about your own laser, get a friend to help you. Shine it against a wall, walk away until your friend stops seeing it and measure the distance. Because the air gets thinner above you, it would travel further if you pointed it up. We can even send powerful lasers to the Moon and measure its distance as the light bounces back from mirrors left by astronauts.

WHEN IS RUTTING SEASON AND HOW LONG DOES IT LAST FOR?

Steven Kingsley

The rut is the name of the mating season for ruminant animals such as deer and elk and is triggered by the shortening length of daylight hours. The timing of the rut depends upon the gestation period for different species, usually occurring so the young can be born in the spring when the weather is milder and there's plenty to eat. The largest land mammal in the UK is the red deer, and their rutting season runs from October to early November. The stags compete against one another for mating rights to a group of hinds called a harem.

What are geodes?

Garry Cook

Geodes are cavities in rocks that are filled with beautiful crystals. The best way to describe how they form is to think of them as gas bubbles that became trapped in the rock as it cooled. Later, mineral-bearing fluids seeped into these gaps, solidifying to either fill or partially fill the cavities. Some of the most impressive geodes are the purple amethyst-lined examples from areas like Brazil or multicoloured agates from Scotland.

WHY DO AARDVARKS EAT ANTS?

Linda Marsh

Ants and termites often live in large numbers and are a nutritious food source if you can get enough of them. The aardvark, which is from Africa, is just one species that has become highly adapted to this diet. Their sharp claws and powerful limbs are well suited to breaking into termite mounds and anthills, while their long, sticky tongues are perfect for catching these little insects. They also have a specialised stomach which helps grind up their prey.

© Getty

Who would win between a *Spinosaurus* and a *T. rex*?

Jonathan Dowling

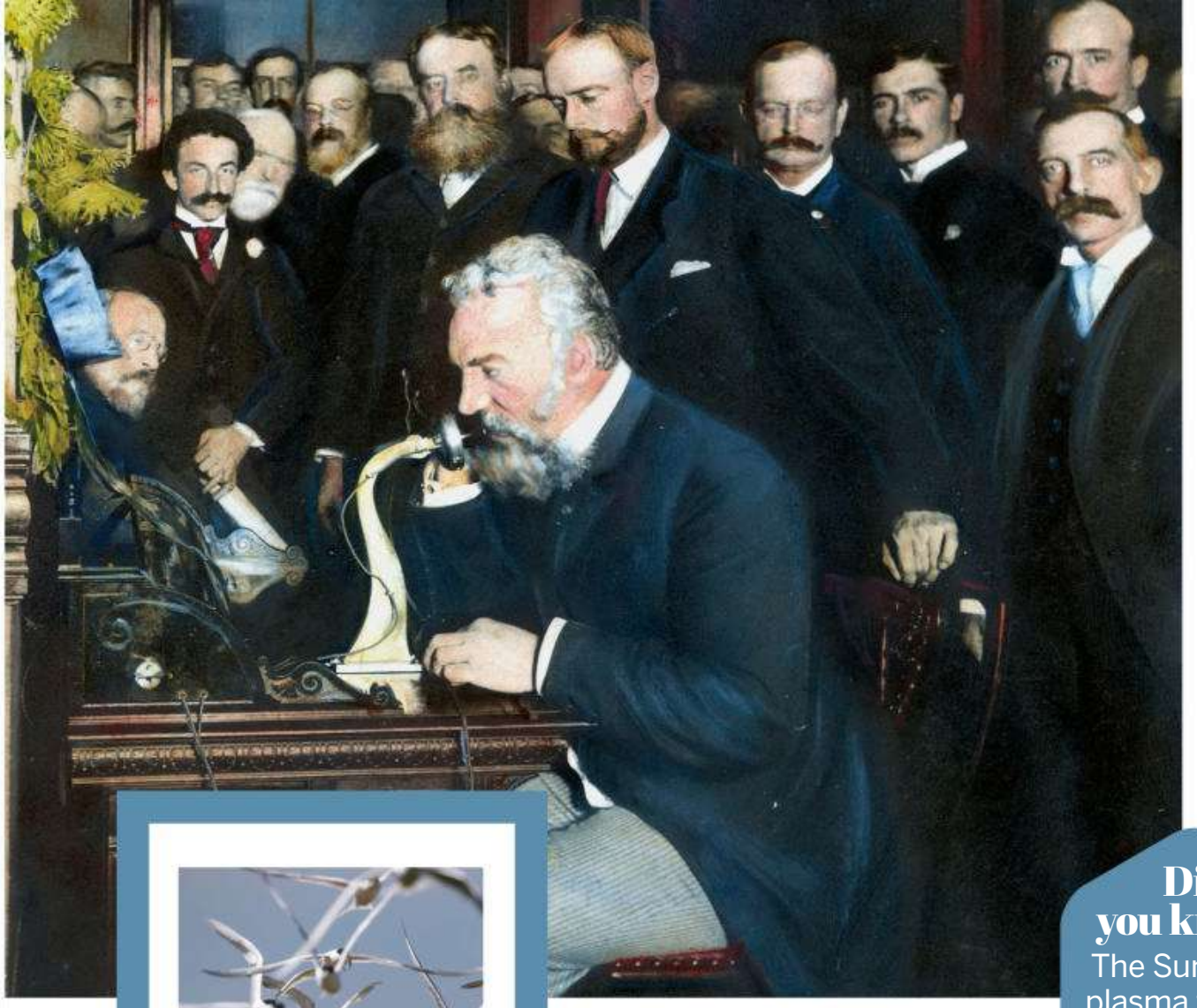
Without a time machine we can only make analogies with living animals to conjecture about the habits and behaviour of extinct creatures. We have only found remains of *Spinosaurus* in Africa and *T. rex* in North America. Moreover, they were separated in time by as much as 30 million years, so they would never have actually come face to face with each other.

But what if we could arrange a meeting between these two super-dinosaurs? Both animals were undoubtedly very powerful flesh eaters. In both, a large skull with an array of dagger-like teeth was the principal weapon. However, *T. rex* had a more robust skull and probably the more powerful bite of the two. The narrower, more elongated snout of *Spinosaurus* suggests a quicker but less powerful bite. Resembling a crocodile's snout, *Spinosaurus* may well have been better adapted to fish eating.

WAS THERE REALLY A PREHISTORIC ALLIGATOR THAT WAS FIVE TIMES THE SIZE OF THOSE ALIVE TODAY?

Simon Manning

Deinosuchus is a large alligatoroid from the Late Cretaceous period of North America. It is in the same superfamily, but not an ancestor, of today's alligators. Its body length is thought to have been up to 12 metres. The remains are incomplete, which makes it hard to accurately measure its length, but it's possible to compare the bones with those of smaller alligator skeletons to get a rough size. Its maximum weight was said, in the journal *Nature* in 1999, to be between three and five times the weight of today's largest crocodilians.



HOW DID THE FIRST PHONE CALL WORK?

Sandra Camado

Alexander Graham Bell's big breakthrough came on 10 March 1876 when he used what he called a 'liquid transmitter'. This was a vertical metal cone with a piece of parchment stretched like a drum over its narrow end at the base. On the outside of the parchment, Bell had glued a cork with a needle stuck in it, pointing into a tiny cup of diluted sulphuric acid.

When he shouted into the open end of the cone, his voice made the parchment vibrate, so the needle moved slightly in relation to a contact in the cup. The needle was wired to a battery and the movement varied the strength of the current passing between the contacts, thus converting sound waves into an electric signal which travelled along a wire to a receiver.

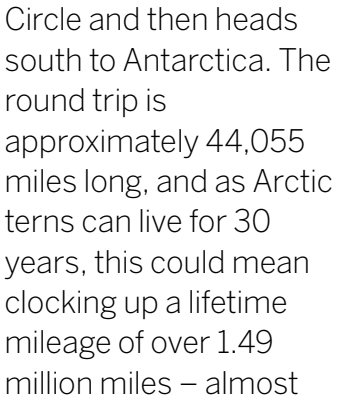
While setting up the experiment, Bell spilt some acid on his trousers. Shouting to his assistant, Thomas Watson heard the message on the receiver in another room and rushed through to Bell, who had just made the first phone call.

Did you know?
The Sun ejects plasma from its violent surface

WHAT IS PLASMA?

Francis Mendez

Plasma can actually mean two different things in science. In biology, plasma is the straw-coloured liquid component of our blood. It's the liquid that all our red and white blood cells, alongside platelets and nutrients, are carried in. Plasma also refers to the fourth state of matter that exists alongside solid, liquid and gas. Plasma is similar to a gas, but in plasma the atoms are ionised. Ionisation means that some of the negatively charged electrons are separated from the atom. This gives the remaining atom an overall positive charge, while the separated electrons have a negative charge. This type of plasma exists in neon signs and stars like the Sun.



WHICH BIRD MIGRATES THE FURTHEST?

Dave Bankes

The longest regular migratory flight is made by the Arctic tern, which breeds in the Arctic Circle and then heads south to Antarctica. The round trip is approximately 44,055 miles long, and as Arctic terns can live for 30 years, this could mean clocking up a lifetime mileage of over 1.49 million miles – almost three return trips to the Moon! The longest non-stop flights are made by various swifts. It has been calculated that young common swifts breeding in Europe and wintering in Africa complete a non-stop flight of some 310,685 miles.

Why are moths attracted to light?

Peter Macknik

Nobody really knows for sure, but moths are thought to use the Moon as a point of reference to travel in a straight line. This might help explain why more moths seem to be attracted to artificial lights on nights when there is no Moon. If moths are drawn in very close to a bright light source, they may become dazzled due to their eyes being unable to adjust quickly enough to the sudden brightness, so they will circle the light instead of flying away from it.

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The latest book releases for curious minds

THE WHO, WHAT, WHY OF ZOOLOGY

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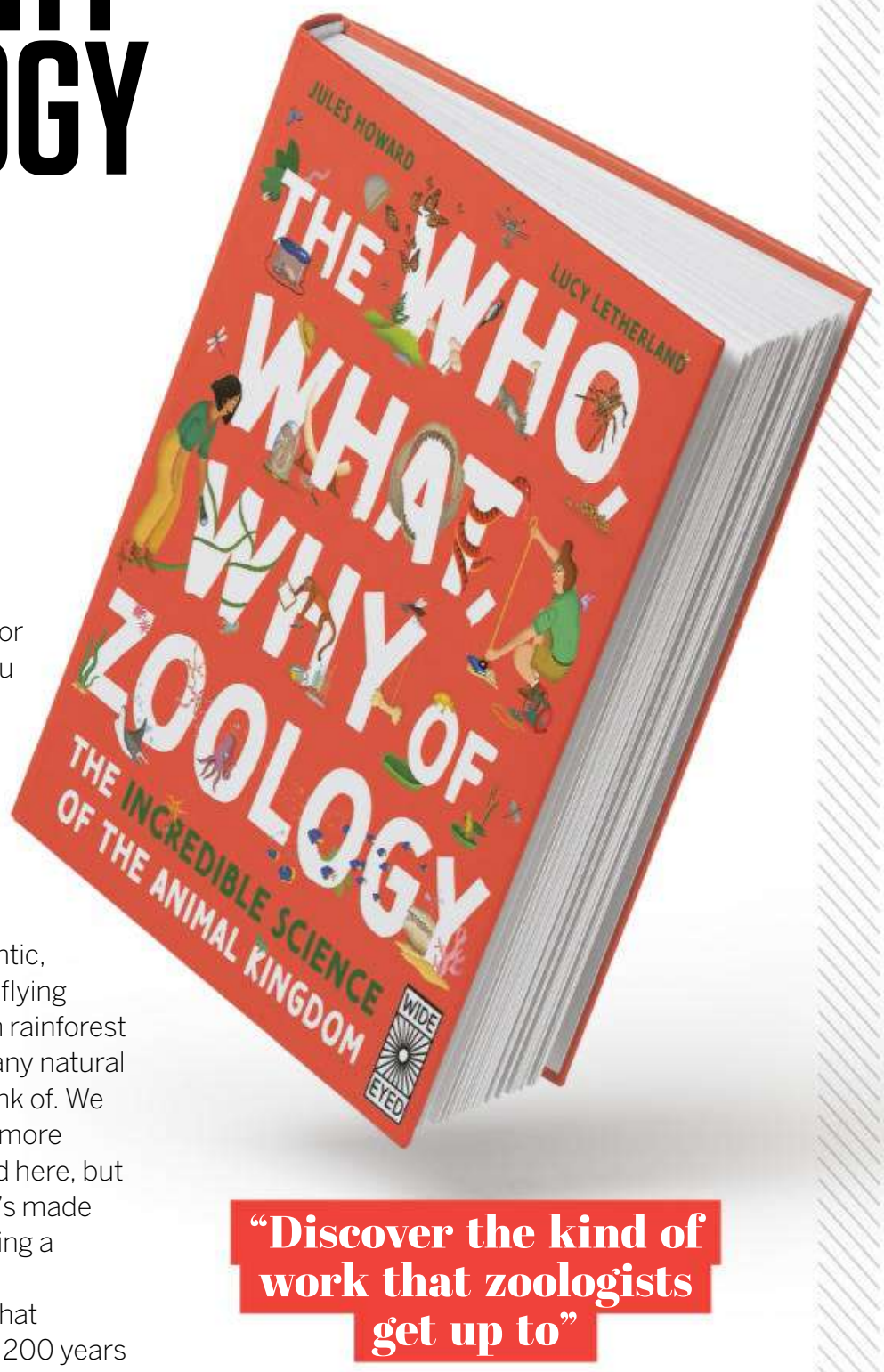
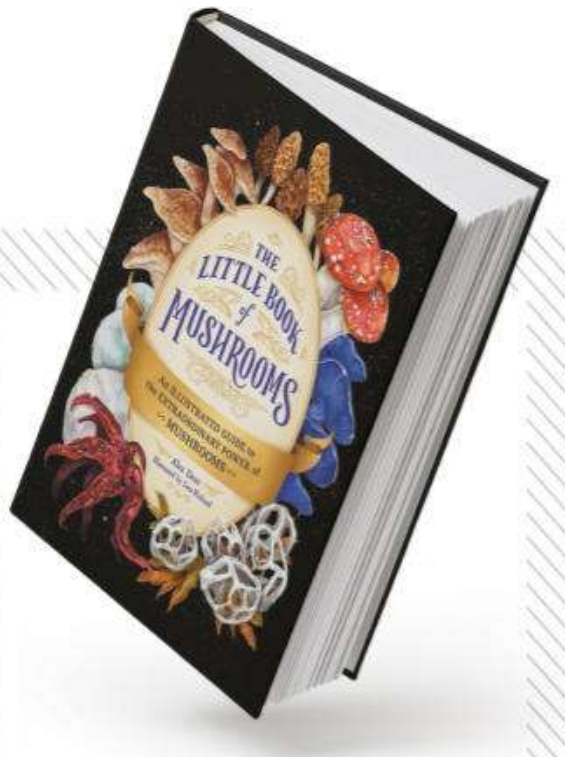


Science presenter and author Jules Howard is inviting you to step into the shoes of a zoologist, arguably one of the most interesting and certainly well-travelled jobs on the planet. At least, if *The Who, What, Why Of Zoology* is anything to go by, then the science of studying animals involves swimming with blue whales in the Atlantic, catching invasive beetles in the Arctic, flying drones above the canopy of a Brazilian rainforest and wild beast-watching in just about any natural environment on Earth that you can think of. We suspect that the job involves a degree more laboratory work than what's suggested here, but in the latter half of this book, even that's made out to be a more fascinating part of being a zoologist than we imagined.

After a little history of this vocation that compares modern zoologists to those 200 years ago in Darwinian times, you're taken on a tour of the planet to discover the kind of work that zoologists get up to – and the 'who, what, why', of course: what any sensible zoology practitioner should wear while scouring a hot desert, who calls the shrinking tropical coral reefs of the world their home, and why computers and advancing technology are so crucial to lab and field work. This science is inextricably woven into the study of the environment, so you can't talk at any length about zoology today without mentioning climate change and the devastating damage that humans are doing to the natural world. *The Who, What, Why Of Zoology* details habitat destruction, extinction and human pollutants, a part of the discussion on the survival of various species. Zoology is very much front and centre here, so environmentalism is too – that's just the world we live in today.

"Discover the kind of work that zoologists get up to"

Lucy Letherland's art is as vital to *The Who, What, Why Of Zoology* as the writing – everything from small pictures of animals right up to full-page illustrations of their environments, including some thought-provoking spreads, such as the deep ocean illustration of a whale skeleton being feasted upon by bottom feeders (which we're sure was inspired by an episode of David Attenborough's seminal *Blue Planet* series). It's a good read for kids and adults alike.



THE LITTLE BOOK OF MUSHROOMS

AN ILLUSTRATED GUIDE TO MUSHROOMS

AUTHOR **ALEX DORR**
ILLUSTRATOR **SARA RICHARD**
PUBLISHER **ADAMS MEDIA**
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The Little Book of Mushrooms is one of the best guides around to the world of mushrooms. It's divided into two parts: the first delving into the science behind fungi, their biology, how they reproduce and their ecology; and the second half explores 75 of the world's most fascinating mushroom species and their characteristics.

You might be surprised by how many forms and functions that mushrooms have, such as the eerie appearance of the dead man's finger fungus (Xylaria polymorpha) or the hissing Devil's Cigar (Chorioactis geaster). The whimsical page design and breathtaking illustrations make walking through the woods on the hunt for fungi feel like something out of a fairy tale.

Although *The Little Book of Mushrooms* and its illustrations are beautiful, it shouldn't be your sole use of a reference guide if you're looking to forage for mushrooms safely.

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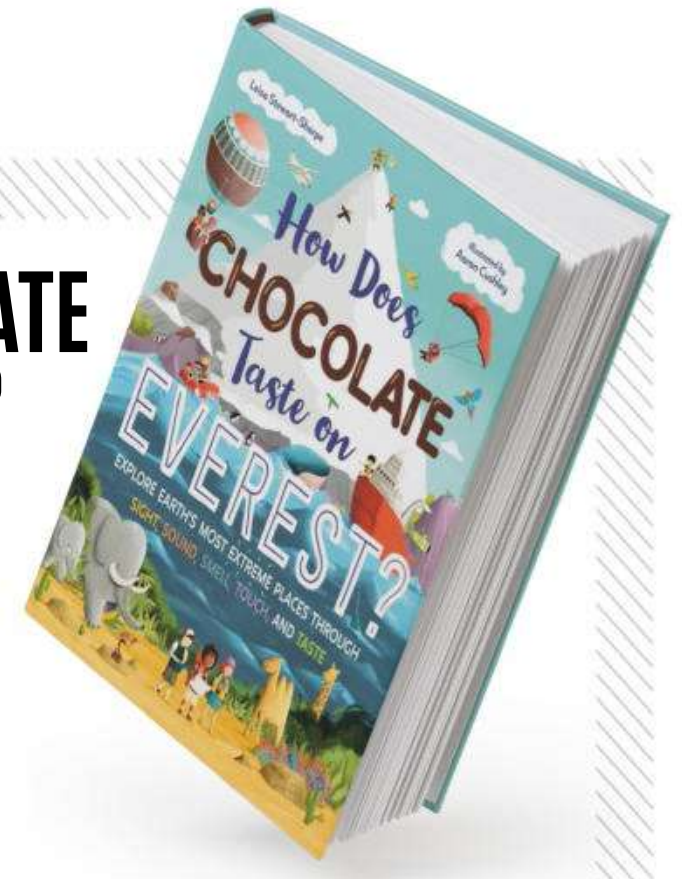


This isn't your typical children's book, nor is it a night-time read: it's an action-packed adventure around the world. Young adventurers will step into the footsteps of the greatest explorers, using their senses as their guides.

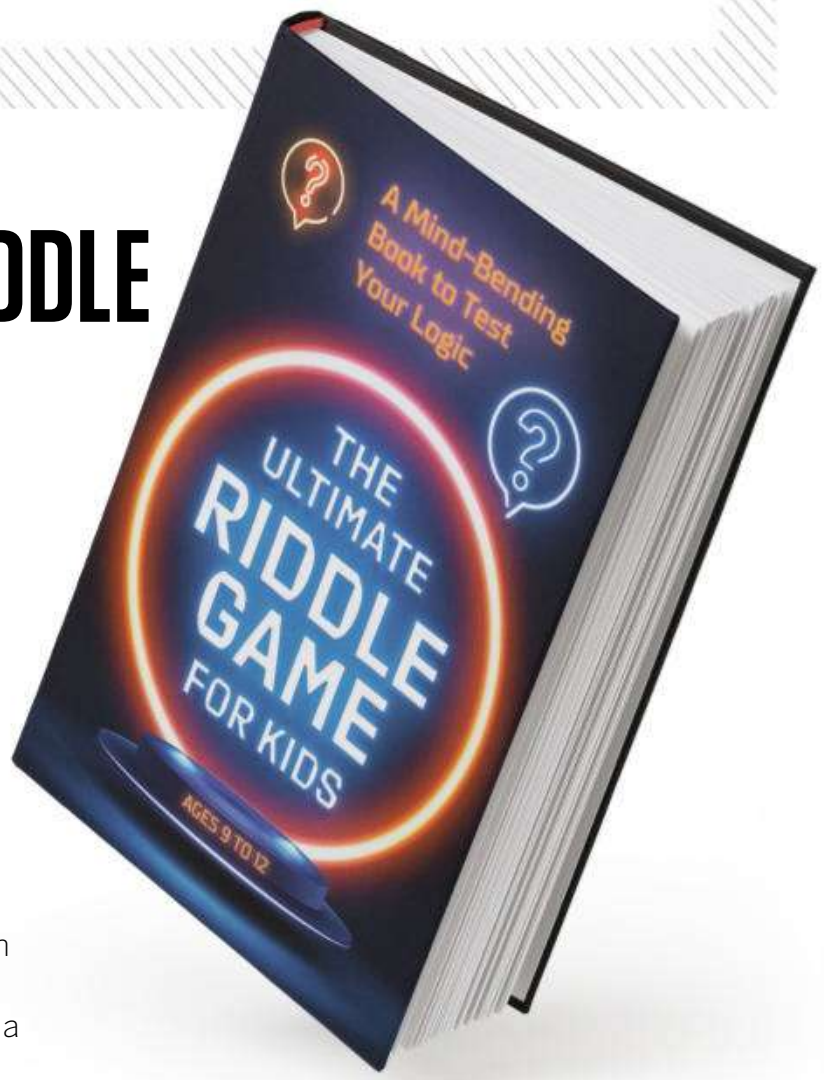
From the smell of burning frankincense along the Nile to the sound of barking sledge dogs in Greenland, this book immerses its young readers in life in the world's most fascinating habitats, countries and continents, as well as those on other planets.

How Does Chocolate Taste On Everest? is packed with fun facts about each location, as well as the people and wildlife that live there. Although there are plenty of children's titles out there that explore wonderful places around the world, there are few that will inspire the next generation of explorers more than this.

THE ULTIMATE RIDDLE GAME FOR KIDS

A MIND-BENDING BOOK TO TEST YOUR LOGIC

AUTHOR **Z KIDS**
PUBLISHERS **ZEITGEIST, PENGUIN RANDOM HOUSE**
PRICE **£9.99/APPROX $12.50**
RELEASE **OUT NOW**



I'm around the same age as the planet, but every month I'm reborn. What am I? For readers between the ages of 9 and 12, this fun riddle book combines logic challenges, competitive contests and brain training. With a score sheet at the back, you can compete against your friends and family as you work through each section, or just test your own lateral thinking skills by playing solo.

The three sections – tricky quick-hitters, maths monsters and sneaky stories – demonstrate the different methods of thinking you need to succeed at finding the answer. The first section consists of short, snappy riddles, the maths section requires mental arithmetic, and for the stories section you will need to take your time to discover all the possible hidden meanings. But try not to cheat.

As the sections get more challenging, you might be tempted to find the answer immediately. The book is much more rewarding when you take the time to improve your problem-solving skills. As you begin to understand the best way to approach each riddle type, your confidence, resilience and score is likely to grow. Oh, and what am I? The Moon, of course!

THERE'S NO CREAM IN CREAM SODA

FACTS AND FOLKLORE ABOUT OUR FAVOURITE DRINKS

AUTHOR **KIM ZACHMAN**
ILLUSTRATOR **PETER DONNELLY**
PUBLISHER **RUNNING PRESS KIDS**
PRICE **£12.99/ $16.99**
RELEASE **18 JULY 2023**

The only drink humans need is water, but the beverage industry is growing larger every year. This book explores the history of the invention of drinks, beginning thousands of years ago, when humans first added natural flavourings to their water as it boiled over the fire.

From the extensive caffeinated beverages available to you when you enter a cafe, to alcoholic beverages or juice and soda combinations, this book could provide you with a new fascinating fact for every drink you've ever consumed. Did you know that plant-based milks have been around since the 13th century? Or that consuming coffee helps to open your airways? What about the fact that there's no cream in cream soda?

The humorous and conversational narrative of *There's No Cream In Cream Soda* means that you have no idea what you will learn with the next turn of the page. Ranging from core scientific processes to the unlikely origin stories of some sodas, this book is sure to have a story to intrigue everyone.

BRAIN GYM

Give your brain a puzzle workout

Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

		4	9		2		1	
		1		8	6		3	
	3	9	4	5		6	2	8
3	4		2	6	9			
	8				4			
				7		2		6
		3	1	9		8		
1	5	2	6			7		3
		8	3		7	4		1

MEDIUM

2	7			6				
		3		4	7			
6	1	5						2
	9		8					4
	4						6	
	5	2		9			7	
			4			3	2	7
	3		7			9		6
7	2		5	3	6			1

HARD

		3		8				
		7	6	5				
4	2						3	
	9				1			
	7		2			4		
	6					5		
1		9				7		
	4				9	8	1	
5		6			4			3

Word search

Find the following words

ASTEROID
IMPACT
VERTICAL
PEST
HOOF
SCUBA
CARDIO
GASTRIC
GLITTER
HIDDEN
BOMB
SPEAKER

F	O	O	L	F	A	N	B	U	B	A	U	N	G	E
A	S	T	E	R	O	I	D	A	F	G	O	M	L	B
G	L	I	T	T	F	R	A	S	T	C	I	R	I	O
C	J	H	I	D	D	E	N	S	P	E	A	K	T	E
P	E	S	L	C	U	B	Z	O	M	T	B	I	T	D
V	I	R	T	E	C	L	I	U	S	E	M	P	E	I
Z	O	W	I	M	P	A	M	E	C	L	H	P	R	Q
L	A	R	D	I	E	O	P	O	F	H	O	Q	F	A
A	L	K	G	A	S	T	A	N	O	B	O	M	B	V
C	D	O	I	D	R	A	C	S	P	A	F	K	M	R
I	F	W	N	O	L	D	T	I	A	N	O	H	I	D
T	D	E	S	P	E	A	K	E	R	N	L	A	C	I
R	T	R	E	V	N	E	D	D	L	S	R	O	A	S
E	Y	R	B	D	S	C	U	B	A	F	L	O	B	P
V	A	T	E	M	P	O	X	C	I	R	T	S	A	G

What is it?

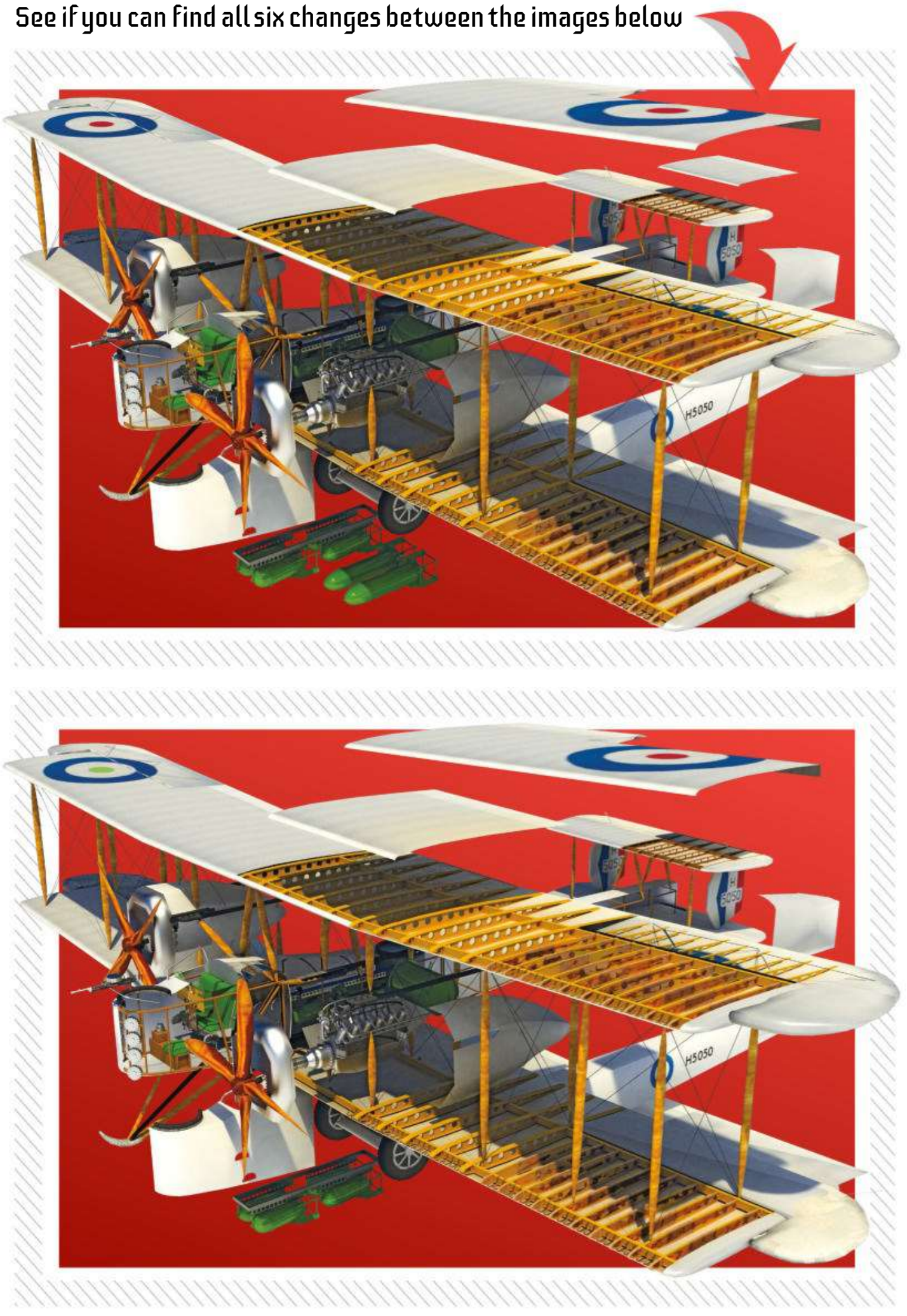
Hint:

A tasty nightshade

A

Spot the difference

See if you can find all six changes between the images below



QUICKFIRE QUESTIONS

Q1 Approximately how much data will be generated on the internet in 2023?

- 120 megabytes
- 120 terabytes
- 120 petabytes
- 120 zettabytes

Q2 About how much of this data will be video?

- 30 per cent
- 40 per cent
- 45 per cent
- 55 per cent

Q3 Oil, coal and natural gas are all:

- Renewable energy
- Fossil fuels
- Biofuels
- Geothermal energy

Q4 Galileo Galilei discovered four moons of which planet?

- Mars
- Venus
- Uranus
- Jupiter

Q5 How fast can a peregrine falcon dive?

- 55 miles per hour
- 186 miles per hour
- 238 miles per hour
- 792 miles per hour

Q6 What is the only rock that can float on water?

- Granite
- Pumice
- Basalt
- Limestone

Answers

Find the solutions to last issue's puzzle pages

Q1 BURNT GUNPOWDER
Q2 LITTLE MOUSE
Q3 400 GRAMS
Q4 CARBON DIOXIDE
Q5 A LIGHT BULB
Q6 1907

What is it?

JET ENGINE

Spot the difference

© Getty

HOW TO...

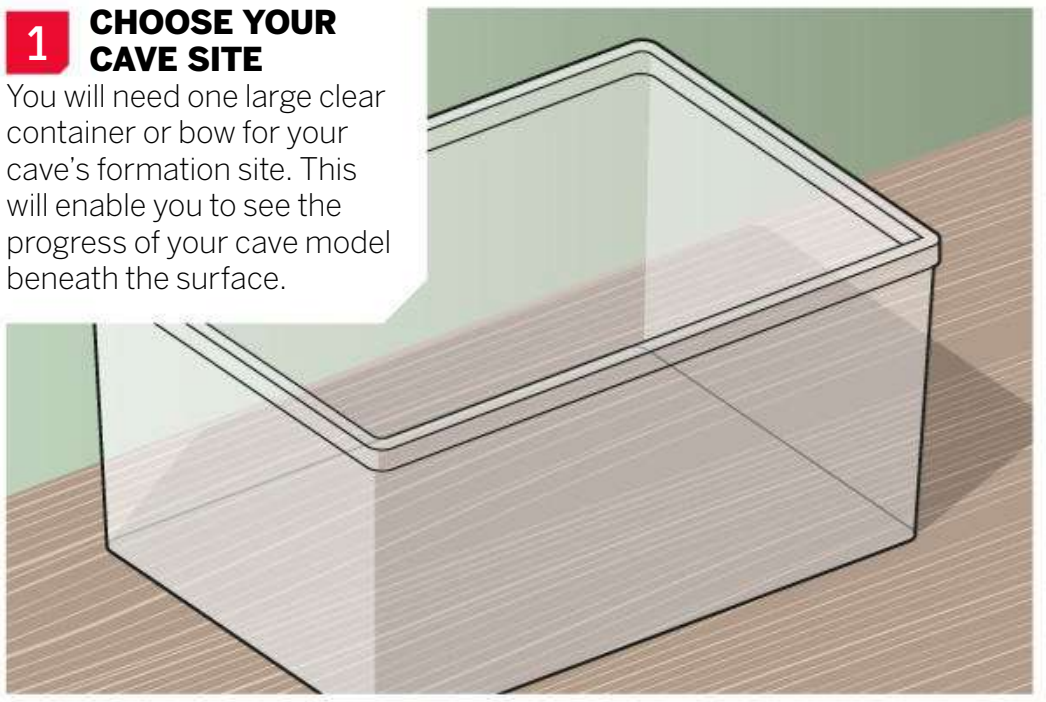
Practical projects to try at home

KIT LIST

- 1 x large clear container
- 1 x toothpick/ skewer
- Sugar cubes (enough to half fill container)
- Plasticine
- Spray bottle
- Food colouring (optional)
- Ornaments to decorate (optional)

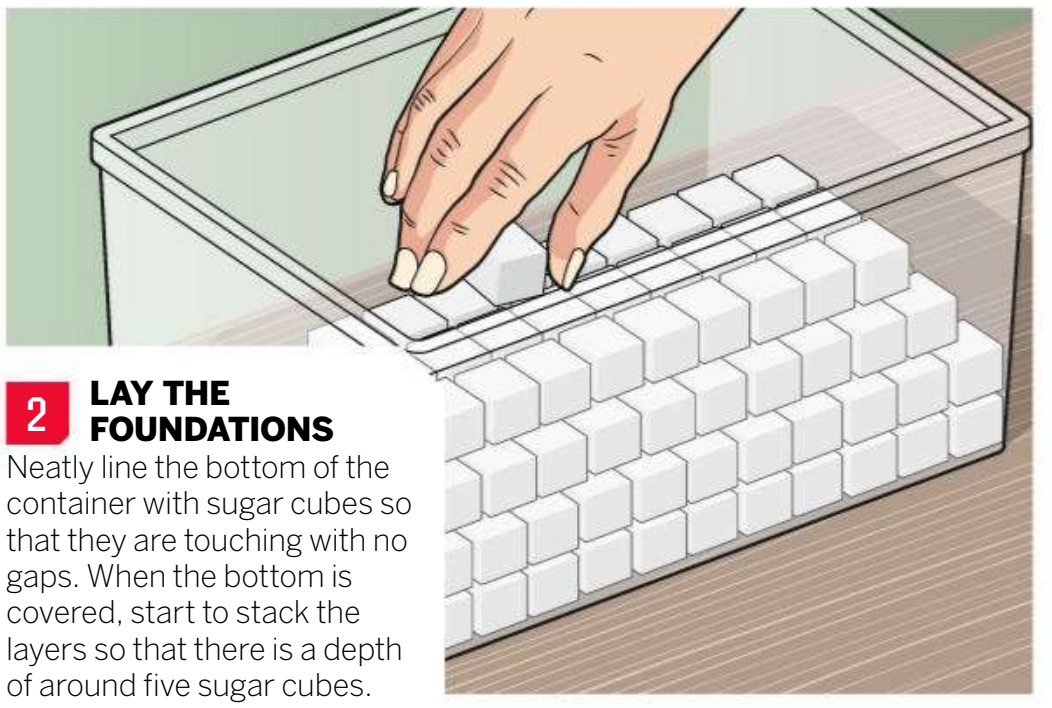
HOW TO MAKE A CAVE

Create your own cave model using sugar to see how Earth's underground spaces form



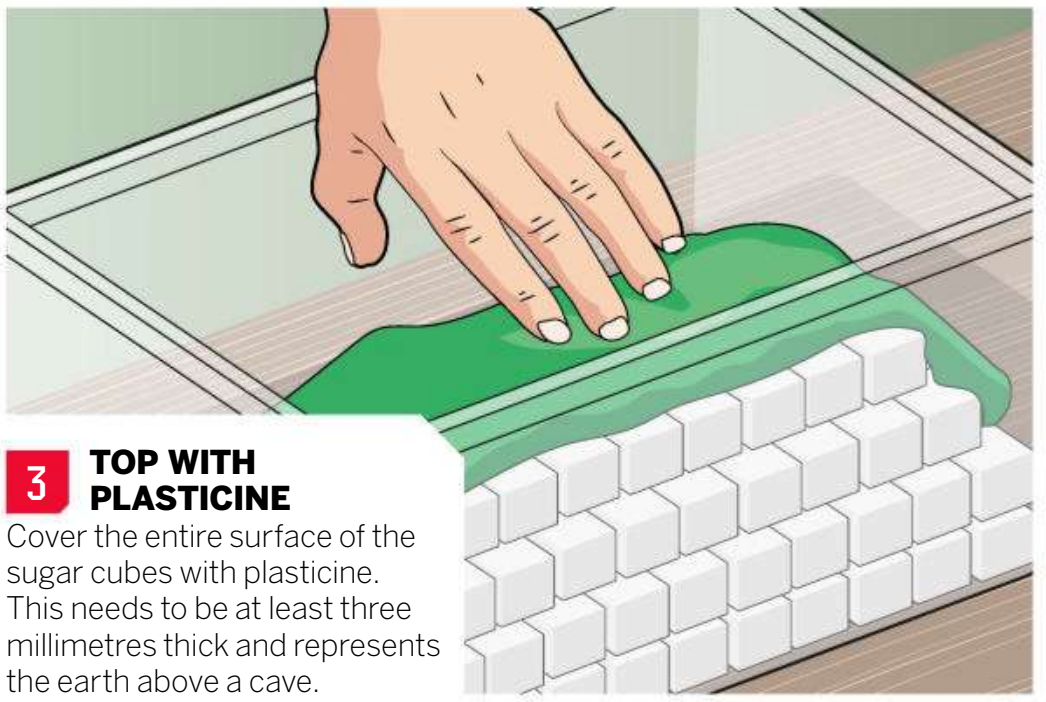
1 CHOOSE YOUR CAVE SITE

You will need one large clear container or bow for your cave's formation site. This will enable you to see the progress of your cave model beneath the surface.



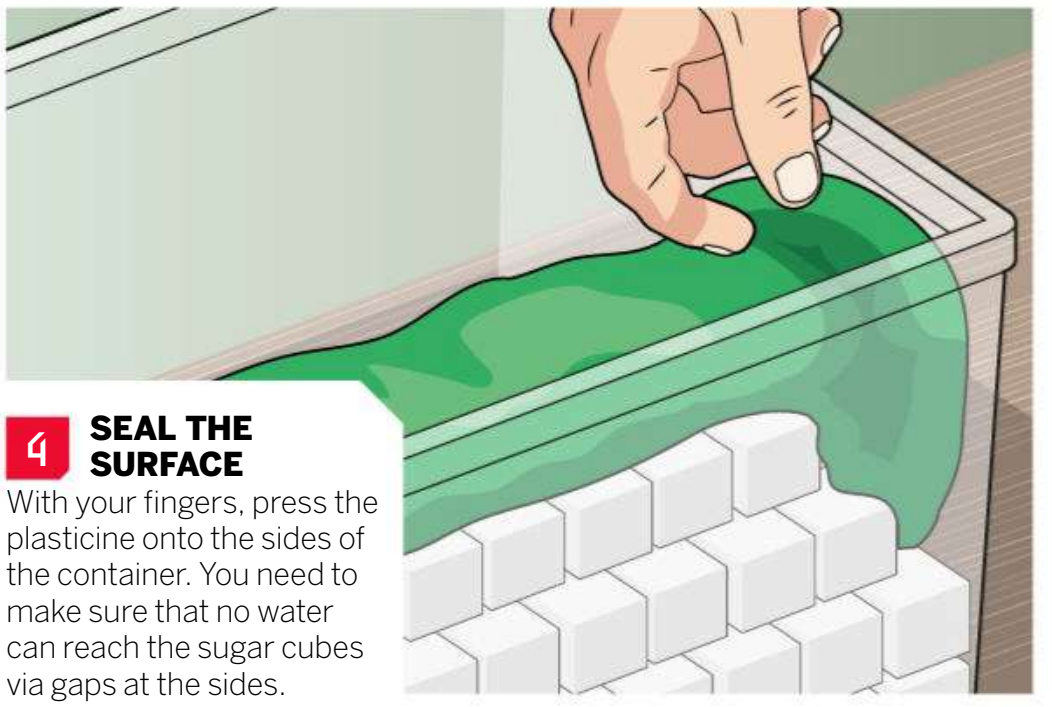
2 LAY THE FOUNDATIONS

Neatly line the bottom of the container with sugar cubes so that they are touching with no gaps. When the bottom is covered, start to stack the layers so that there is a depth of around five sugar cubes.



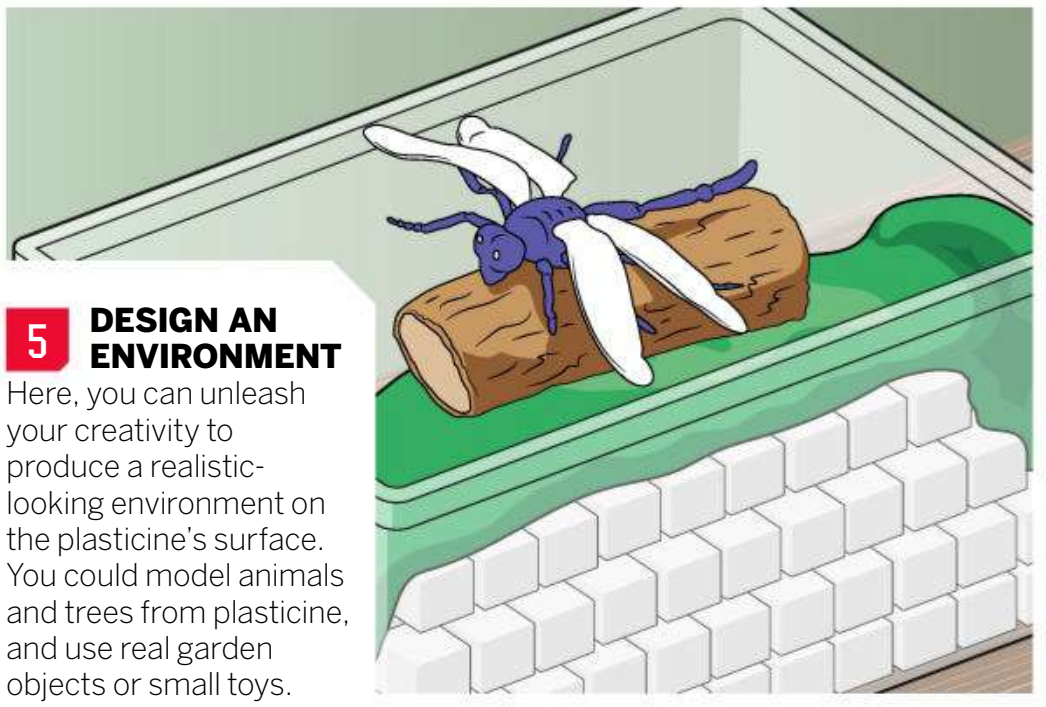
3 TOP WITH PLASTICINE

Cover the entire surface of the sugar cubes with plasticine. This needs to be at least three millimetres thick and represents the earth above a cave.



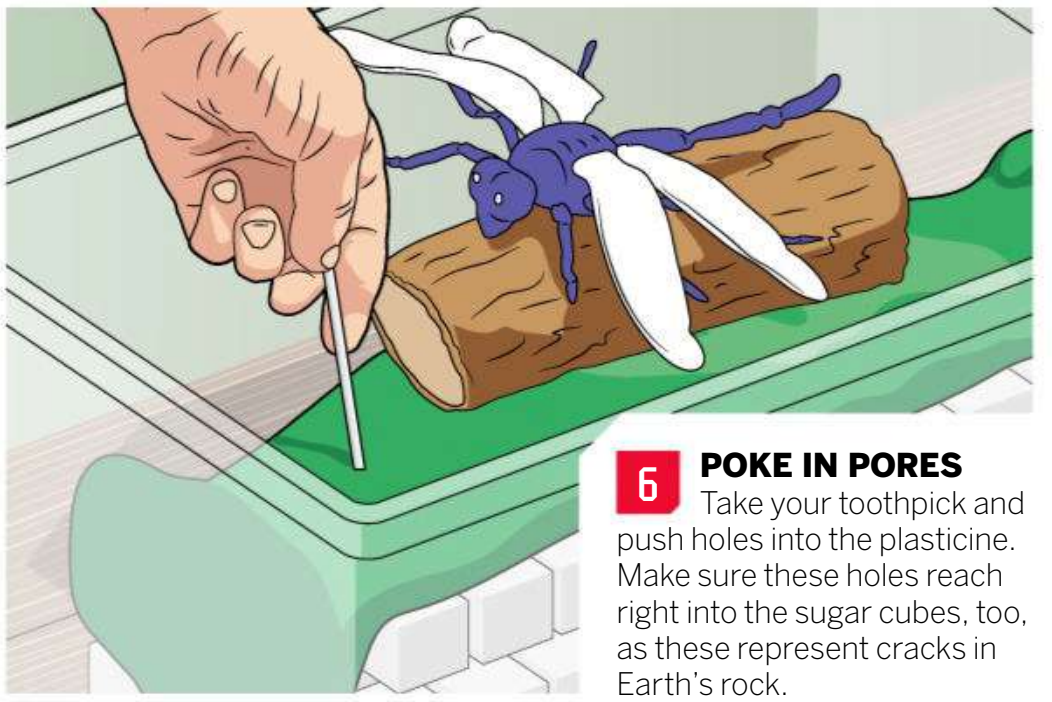
4 SEAL THE SURFACE

With your fingers, press the plasticine onto the sides of the container. You need to make sure that no water can reach the sugar cubes via gaps at the sides.



5 DESIGN AN ENVIRONMENT

Here, you can unleash your creativity to produce a realistic-looking environment on the plasticine's surface. You could model animals and trees from plasticine, and use real garden objects or small toys.

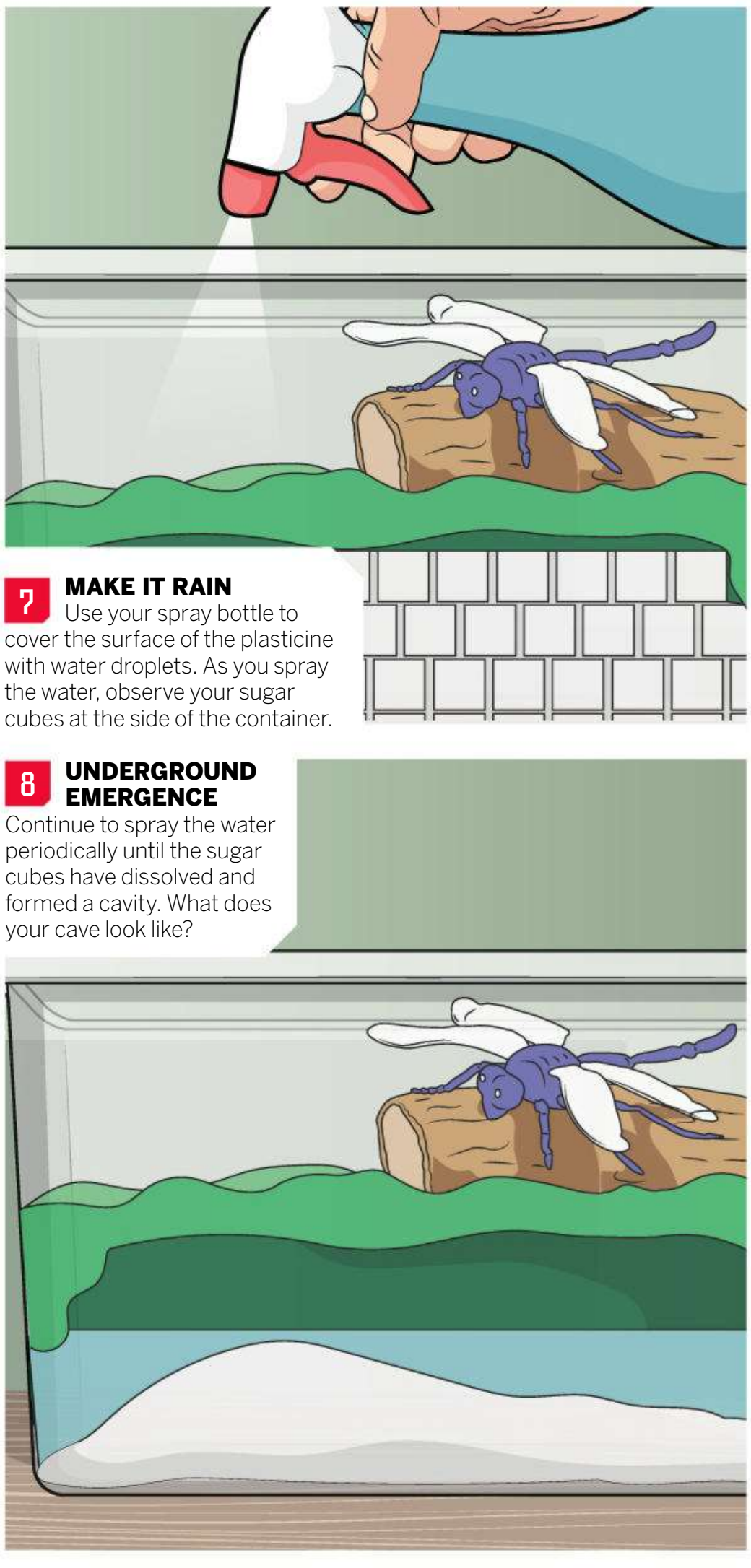


6 POKE IN PORES

Take your toothpick and push holes into the plasticine. Make sure these holes reach right into the sugar cubes, too, as these represent cracks in Earth's rock.

DON'T DO IT ALONE!

If you're under 16, make sure you have an adult with you



7 MAKE IT RAIN

Use your spray bottle to cover the surface of the plasticine with water droplets. As you spray the water, observe your sugar cubes at the side of the container.

8 UNDERGROUND EMERGENCE

Continue to spray the water periodically until the sugar cubes have dissolved and formed a cavity. What does your cave look like?

SUMMARY

Caves usually form over the course of a few million years, but with this experiment you can watch the simplified process condensed into a matter of minutes. As the water is sprayed onto the plasticine, which represents the periodic rainfall that occurs over Earth's surfaces, it slowly seeps into the gaps in the plasticine and sugar. The sugar represents the limestone rock that is a common site for cave formation. When the water mixes with the sugar, the water molecules attract the sucrose molecules in the sugar and begin to pull them apart. The smaller molecules of the sugar are surrounded by the water molecules and become too small to be seen. The water continues to move through the sugar and carries it away from the centre of the container, forming a cavity. When slightly acidic rainwater seeps through Earth's limestone rock, a similar process occurs to make real caves. To better track the movement of water, you can add food colouring to the water in the spray bottle.

Had a go? Let us know!

If you've tried out any of our experiments – or conducted some of your own – let us know! Share your photos or videos with us on social media.

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INBOX
Speak your mind

Sand grains are generally between 0.06mm and 2.0mm in size

THE STORY OF SAND

Dear **HIW**,
Geography has always been my favourite subject and your magazine always teaches me interesting new facts. I wondered if you could answer my question. How long does it take to make the sand on beaches from rocks and how much does sand move over time?
Emily Derrick

Thanks for your letter, Emily. It's great to hear you have a passion for geography and that you're keen to further your knowledge. Sand is so plentiful along the world's coastlines and in deserts, but each tiny grain actually takes a very long time for nature to craft. It can take thousands or millions of years for sand to be produced through the gradual process of breaking down larger rocks. This depends on factors such as the hardness of the rock type and the climate conditions that the rock is subjected to.

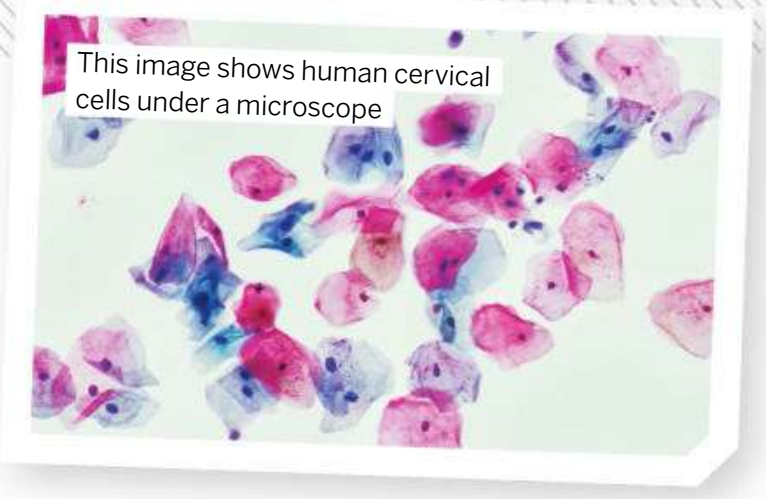
LETTER of the MONTH

The most common form of sand found on beaches is derived from granite rock. This is broken down by wind and water and can start many miles away from the beach you find it at. Usually, rock moves with the flow of rivers and streams towards coastlines, broken up by the water and surrounding objects as it travels. At the ocean, small rock pieces are further broken down by the movement of the sea. This includes crashing waves and the constantly changing tide. The ocean's surf zone pushes sand grains along the coastline in the direction of the swell so that in just a few hours, a sand grain could move miles along the beach. The sea isn't the only factor in reorganising a beach's foundations. During a significant storm, winds can pick up the tiny rock particles and blow them far offshore in just a few minutes. So, while beaches appear relatively permanent, each grain is on its own individual journey.

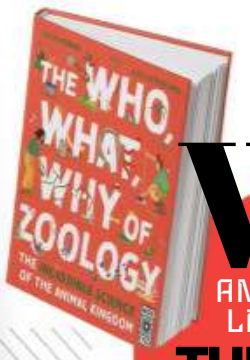
BUILDING BLOCKS OF LIFE

Dear **HIW**,
I have a question about cells. Cells are made up of water, ions, and carbon-based molecules. All these are abiotic. But how do these form together to create life?
Grant Yiu

This is a great question. Living (biotic) things are made up of non-living (abiotic) components, and it is the role of DNA inside cells to control how these components are incorporated into the production of new cells. However, for the first cells to come into existence, abiotic material needed to form a biotic cell without the assistance of pre-existing cell DNA. Scientists don't know for sure, but use the theory of abiogenesis to explain this event.


This image shows human cervical cells under a microscope

When gases were exposed to large amounts of energy, molecules combined to form more advanced molecules. Eventually (over billions of years) these molecules became complicated enough to become self-replicating like DNA. This molecule has evolved differently in different living organisms, but contains the instructions needed to turn the abiotic components into biotic cells.



WIN!
AN AMAZING PRIZE FOR LETTER OF THE MONTH

THE WHO, WHAT, WHY OF ZOOLOGY
From the deepest oceans to Himalayan valleys, zoologists explore far and wide to better understand the worlds of mammals, birds, fish, reptiles and nearly anything else that can walk, fly or swim.

"HOW'S THAT?"

Dear **HIW**,
When was cricket invented and how has it changed over time? It looks like a relatively old sport that might have kept the majority of its original rules.
Charles Wynter

Cricket is thought to have been invented in southern England as early as the 13th century. During early versions of the game, players would have stood in front of items such as tree stumps instead of specially designed cricket wickets. You are right that the core rules and original layout of the sport have remained intact, but the format we see today has been in place since the late 19th century. Six-ball overs were introduced in 1900 and later more specialist techniques came into play, such as the art of spin bowling.

White clothing makes it easier to see the red cricket ball.

NEXT ISSUE ISSUE 179 ON SALE 6 JULY 2023

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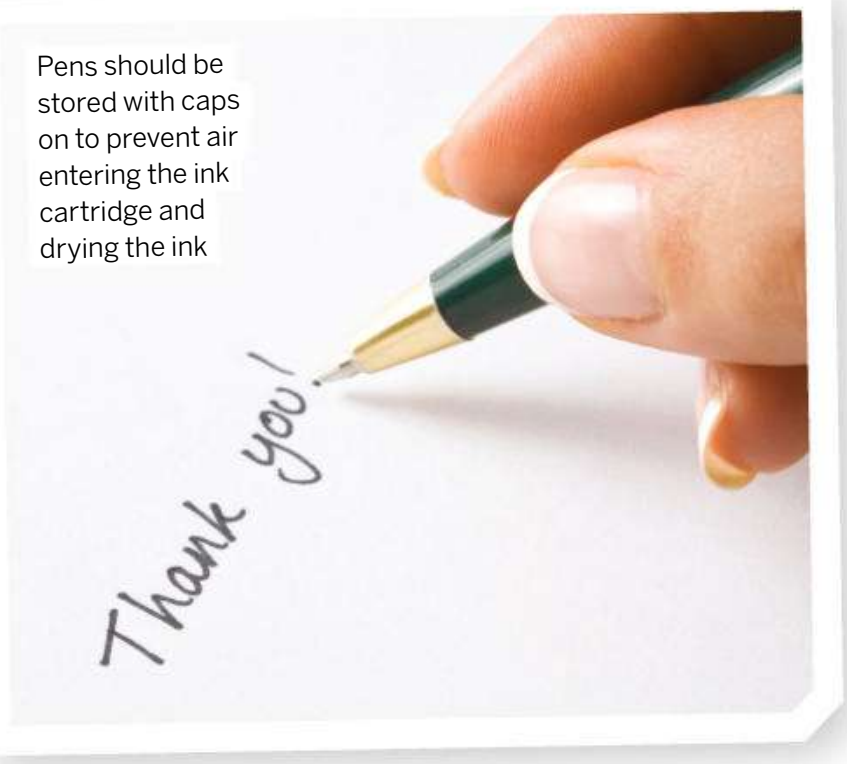
On one charge, most electric car batteries last for 100-200 miles

GOING ELECTRIC

Dear **HIW**,
If electric cars are better for the environment, when will petrol cars stop being sold?
Steven Curry

This is a good question and it depends on where in the world you live. In the UK, for example, the sale of new petrol and diesel cars will be banned in 2030. Later, in 2035 the sale of hybrid cars will also stop. This will mean that only second-hand petrol cars will be sold and eventually they will be phased out completely. Many other places, including Norway, the Netherlands and Croatia are also introducing these bans.



Pens should be stored with caps on to prevent air entering the ink cartridge and drying the ink

PEN TO PAPER

Dear **HIW**,
How does ink dry so quickly on paper but can stay wet for a long time inside a pen?
Josie McAlpine

Thanks for your question, Josie. Ink dries quickly when it is drawn across paper because there is only a small amount of ink that is exposed to the air – the water in the ink evaporates quickly into the air, causing the ink to dry. When inside a pen, the ink has a greater volume. The pen surrounding the ink serves as a barrier between the ink and air so that water can't evaporate and escape.

WE ASKED YOU

This month on social media, we asked you: Which scientist inspires you the most?

@SCIMAXFACTS

Stephen Hawking because he made some great discoveries and breakthroughs!!

JO STEWART

Charles Darwin– He taught us so much about the natural world

@AESTHETICALLY_AJ

Katherine Johnson as she made the calculations behind NASA's major missions and deserved more recognition

TOM WATSON

Brian Cox because watching him on TV got me interested in space

ABBIE R

Jane Goodall for helping us understand the chimpanzee as our closest living relatives

ETHAN BYRNE

Thomas Edison because he achieved so many groundbreaking inventions

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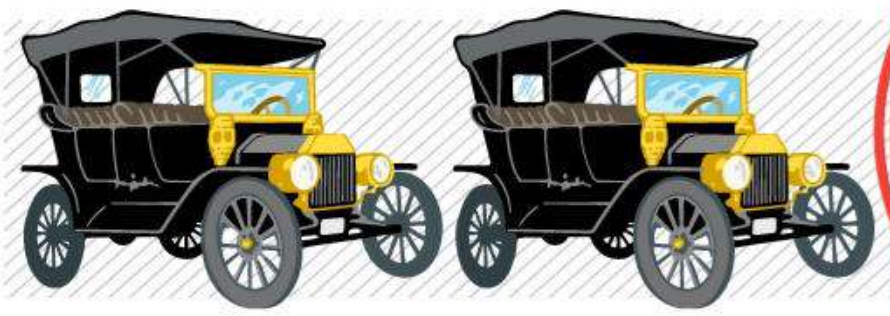
FAST FACTS

Amazing trivia that will blow your mind

5.8 TRILLION MILES

One light-year is over 1,000 times the distance of Earth to Pluto



WHEN HENRY FORD LAUNCHED THE MODEL T IN 1908, IT WAS ONLY AVAILABLE IN BLACK

4.95 BILLION PEOPLE

Over two thirds of the world used the internet in January 2022

20 TIMES A MINUTE

We blink nearly three times more frequently when not looking at a screen

230 LITRES

Our kidneys filter enough blood each day to fill 40 adult humans

29%

Trees cover nearly one third of Earth's land

Mount Vesuvius in Italy is the only active volcano on the European mainland

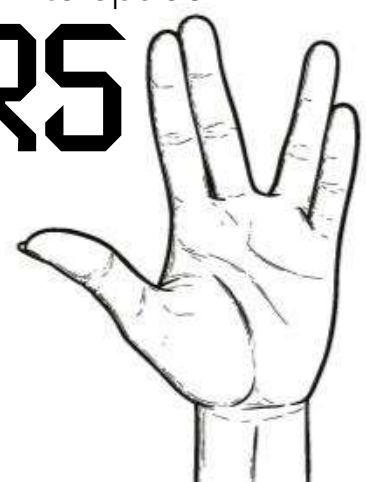
SLOTHS HAVE RIB CAGE VERTEBRAE IN THEIR NECK

18 YEARS OLD

Space tourist Oliver Daemen is the youngest person to fly into space

90 YEARS OLD

Star Trek actor William Shatner is the oldest person to fly into space



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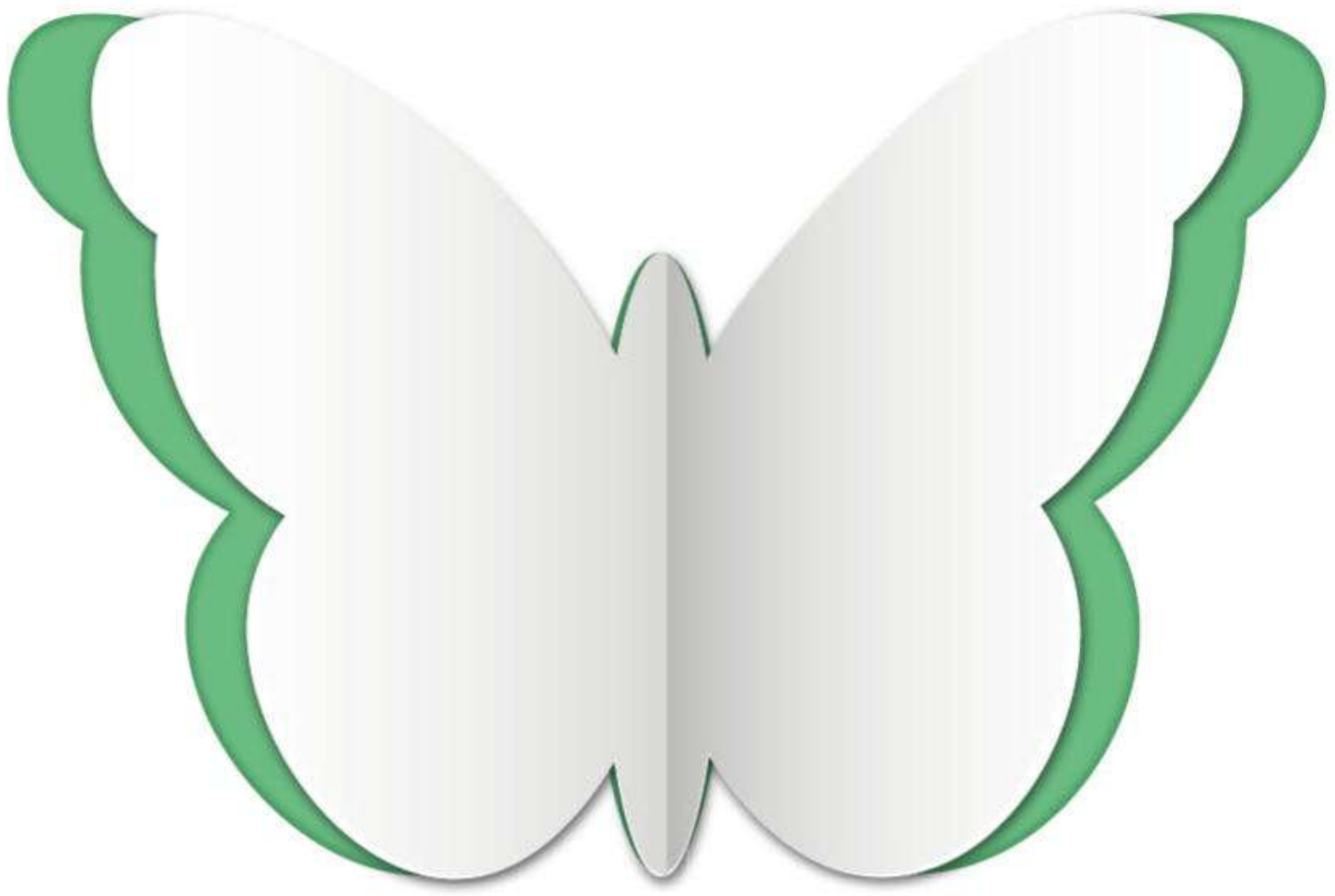

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Source: FAO and UNEP, The State of World's Forests, 2020

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